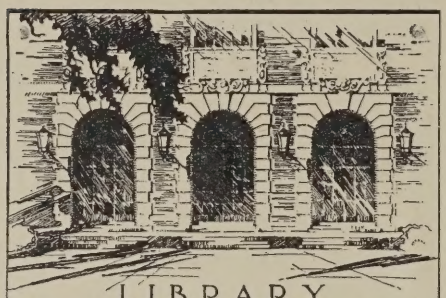

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THE MIGRATION OF ILLINOIS FISHES

David H. Thompson

STATE OF ILLINOIS
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NATURAL HISTORY SURVEY
Theodore H. Frison, Chief

BIOLOGICAL NOTES NO. 1 URBANA, DECEMBER 1, 1933

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THE MIGRATION OF ILLINOIS FISHES

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BIOLOGICAL NOTES NO. 1 URBANA, DECEMBER 1, 1935

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The Migration of Illinois Fishes

by

David H. Thompson

About 7,000 Illinois fishes of the larger and more important kinds have been marked with serially numbered tags and released in the principal streams and lakes of the state. At present we have sufficiently detailed information on the time and place of recapture of more than 120 of these tagged fishes to warrant a preliminary report. Beginning in 1929, Illinois has suffered four years of extreme drouth. During these years unusually low stages of water have prevailed in all of our streams. Since most of these fishes bore tags during this period, the results which we have obtained may reflect in some degree the effects of drouth on fish movements.

It has been found that the movements of fishes as determined by tagging are random in nature, at least in their general aspects and over considerable periods of time. This randomness of their movements is shown by the fact that they are retaken at distances from the starting point proportional to the square root of the time. This relationship of time and distance may be utilized to estimate average distances from the starting point. These calculated average distances are shown in Table I, p. 2 for periods of one day, one week, one month, one year, and five years. This table shows rather accurately the rate at which waters depleted of their fishes, but connected with waters containing desirable kinds, may be restocked by the natural movements of the fishes themselves. It also indicates to what degree we may expect fishes to utilize uniformly the food resources in the different portions of a stream or lake.

These returns from tagged fishes have given information on other questions. Crappies, sunfishes, and basses move upstream strikingly faster than downstream, while, on the other hand, the carp moves downstream rather than upstream. The black bullhead makes rapid upstream migrations in spring and tends to run in schools, since on one occasion an angler caught in one day three tagged bullheads, which had been tagged 15 miles downstream 18 days earlier. A number of instances have given measurements of growth in length and weight over considerable periods of time and enables a check on the rates of growth obtained by counting the annual rings in scales. Striking differences in the capacities of different fishes to carry tags have appeared, certain kinds not carrying tags more than a few days or weeks, while others seemingly carry tags indefinitely.

Table I.—Calculated average migrations in miles over various periods of time.

Kind of Fish	One Day	One Week	One Month	One Year	Five Years
White bass	1.25	3.3	6.8	23.9	53.4
Rock bass	0.79	2.1	4.3	15.1	33.7
Black crappie	1.31	3.5	7.2	25.0	56.0
White crappie	1.19	3.1	6.5	22.7	50.9
Bluegill	0.75	2.0	4.1	14.3	32.0
*Green sunfish	0.04	0.1	0.2	0.8	1.8
Yellow perch	0.14	0.4	0.8	2.7	6.0
Pickerel	0.12	0.3	0.7	2.3	5.2
*Sheepshead	2.06+	5.4+	11.3+	39.3+	87.9+
Black bullhead	1.26	3.3	6.9	24.1	53.8
Flathead cat	0.81	2.1	4.4	15.5	34.6
*Channel cat	0.08	0.2	0.4	1.6	3.5
*Common redhorse	0.10	0.3	0.5	1.9	4.3
Black sucker	0.28	0.7	1.5	5.3	11.9
Quillback	0.50	1.3	2.7	9.5	21.3
Small mouth buffalo	1.07	2.8	5.9	20.4	45.7
Red mouth buffalo	1.73	4.6	9.5	33.1	73.9
Carp	0.42	1.1	2.3	8.0	17.9

*The reliability of the figures given for these fishes is questionable.

Early in 1926 we started tagging fishes with a hundred aluminum tags furnished by the U. S. Bureau of Fisheries. No further tagging was done until the summer of 1929 when we changed to tags made of non-corrosive metal in two sizes—the so-called No. 2's and No. 3's. These tags bore a serial number on one side and the letters INHS, for Illinois Natural History Survey, on the other. In the course of four seasons of field work, 1929-1932, 7,000 fishes have been tagged as a part of aquatic surveys and fisheries research covering the more important waters of the state. The fishes were usually tagged and released near the spot where they were caught, although occasionally they were released a few miles away. The localities in Illinois where fishes were tagged are indicated in Fig. 1., p. 4.

In order to secure returns from these tagged fishes placards showing an illustration of a fish with a tag attached and worded as follows were posted at places where fishing licenses are sold, boat yards, sportsmen's hotels, fish market boats, resorts, etc.:

WATCH FOR TAGGED FISH

The migration and growth of important kinds of Illinois fishes are being studied by marking them with small metal tags clamped to the upper side of the tail fin. These tags have a number on one side and INHS on the other.

Bass, crappies, blue gills, sunfish, wall-eyed pike, pickerel, sheepshead, channel cat, mud cat, bullheads, carp, buffalo, redhorse, suckers, etc., have been tagged in many parts of Illinois. Records have been kept showing the exact kind, weight, length, tag number, and the place and date that each fish was tagged and released.

We invite fishermen to cooperate by returning the tags and about 10 scales from the middle of the left side of the fish to the

NATURAL HISTORY SURVEY
URBANA, ILLINOIS

with information showing the body of water and exact location where the fish was taken, and if possible, the weight and length.

If desired, the tag will be returned with information showing how far the fish had traveled and how much it had grown since it was originally tagged.

In order to secure returns from those tagged fishes
please write showing an illustration of a fish with a tag attached and
stating as follows were posted at places where fishing licenses
are sold, boat yards, sportsmen's hotels, fish market boards,
Chambers, etc.:

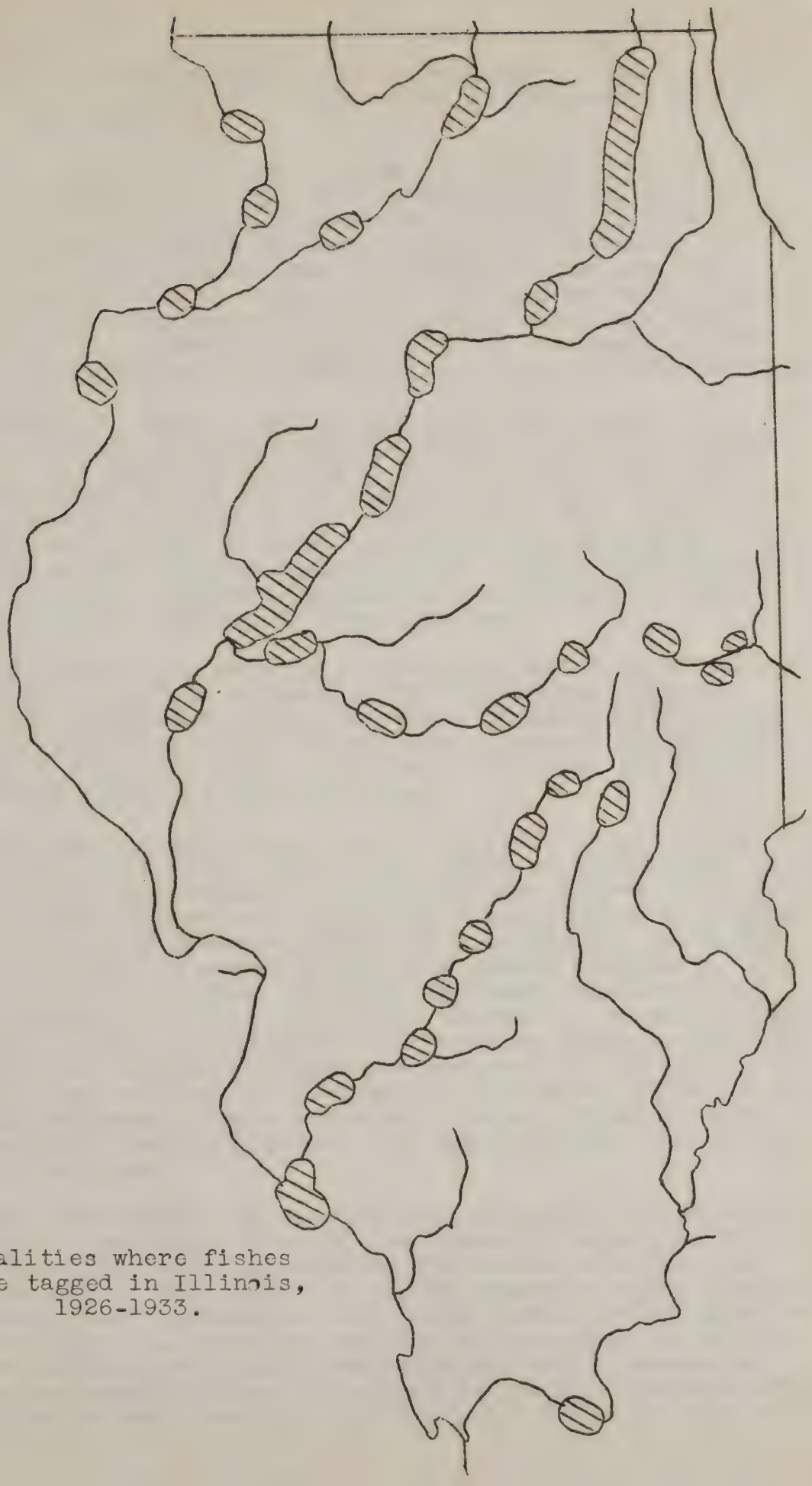
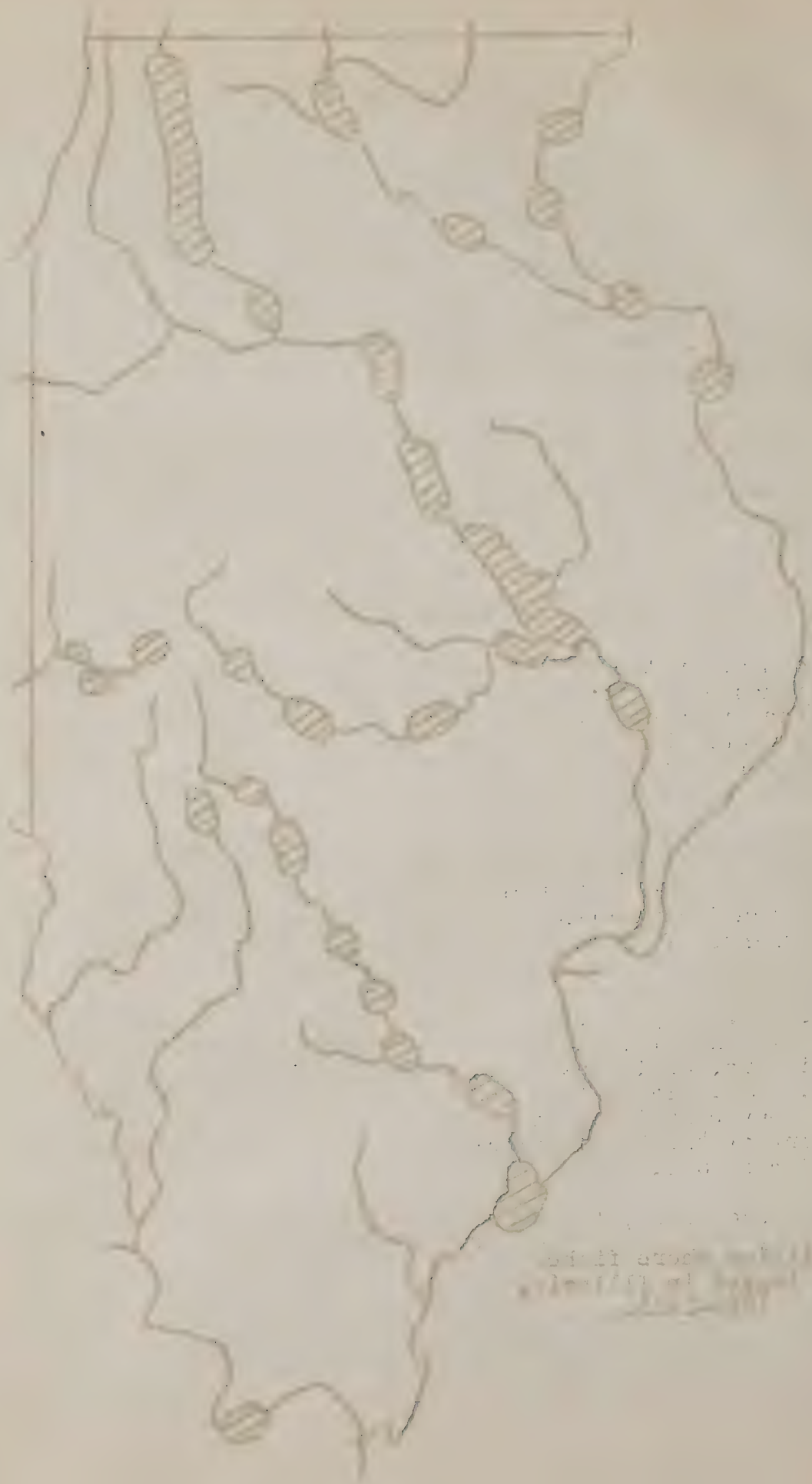


Fig. 1.—Localities where fishes were tagged in Illinois, 1926-1933.



From time to time information given to newspapers told of these experiments and requested the cooperation of hook-and-line and commercial fishermen.

The numbers of fishes tagged are summarized by kinds and streams in Table II, p. 6. The number of returns of tags from the different kinds are summarized in Table III, p. 7. Hook-and-line fishermen returned 45 tags, commercial fishermen 31 tags, while 47 tagged fishes were recaptured in our own nets after one, two, or at most a few days. The maximum and average periods that tags were borne by the different kinds are also given in Table III. Tabulated details of the history of each tagged fish whose capture was reported are given in Table IV, pp.8-16.

Grateful acknowledgments are due those anglers and commercial fishermen who furnished the data on which this report is based. In all parts of the state the field work has been greatly facilitated by commercial fishermen who have given freely of their intimate knowledge of Illinois waters, fish life, and fishing methods. I wish to thank the people who have made up the field parties of the Natural History Survey during these different seasons of field work and especially Mr. Francis D. Hunt, who has been in immediate charge of these parties.

Soon after the reports on the place and date of capture of tagged fishes began to accumulate it was obvious that the shortest water distance from the place the fishes were released to the place where they were retaken was not proportional to the length of time they were free. The longer the time the smaller was the average daily distance traveled.

By watching the movements of fishes in clear waters it appears that there is at least some degree of randomness. In casting about for some method of measuring this degree of randomness, it was found convenient to compare the movements of fishes with the movements of Brownian particles in a liquid, since the latter seem to typify a movement entirely random in nature. The rate of movement of Brownian particles has been expressed in a series of equations by Professor Albert Einstein. Briefly, these equations state that the distance of a Brownian particle from the starting point is, on the average, proportional to the square root of the time. By applying this measure of randomness of movement to fishes it may readily be ascertained whether or not fishes exhibit a sort of "homing instinct," or whether they tend to swim in certain directions.

For each fish, the shortest water distance in miles has been divided by the square root of the number of days the tag was carried. This gives an expression of the number of miles, or fraction of a mile, that this fish may be expected to be distant after one day. Such numbers for different fishes are weighted by the number of days the tags were carried and averaged in various ways to give what may be called composite migration constants. These migration constants may be defined as the calculated average distance in miles away from the starting point after one day of time.

Table II.—Numbers of fishes tagged in Illinois waters to July 1, 1953

Kind of fish	Mississippi River (Savanna to New Boston)	Illinois River & bottomland lakes	Rock River	Kaskaskia River	Sangamon River	Fox River & Fox Lakes	Lakes along Ohio River	Totals
Large mouth black bass	8	161	2		8	51	3	233
Small mouth black bass			12			12		24
Rock bass				17		59		76
Warmouth bass		4				32		36
White bass			1			32	2	35
Yellow bass	6	14				1		21
Black crappie	12	530	7	9	37	224	10	829
White crappie	68	416	52	40	41	152	157	926
Bluegill	2	112	2	1	6	260	21	404
Pumpkinseed				13		16		29
Long-eared sunfish				10				10
Green sunfish		1		1	3			5
Garman's sunfish		1						1
Wall-eyed pike		3	45			2		50
Yellow perch		17				8		25
Pickerel						60		60
Grass pike						1		1
Sheepshead	40	67	77	4	26			214
Eel				4			2	6
Channel cat	71	99	22	74	140	116	2	524
Blue cat				1				1
Flathead cat	13		3	41	30		1	88
Black bullhead	4	45		289	292	89		719
Speckled bullhead		15				101		116
Yellow bullhead		12		1	9	11		33
Carp	88	1228	72	48	113	134	10	1693
Red mouth buffalo		164	8	1	2		2	177
Mongrel buffalo		23	2	1	1		1	28
Small mouth buffalo	1	28		5			15	49
Quillback		34	3	5		5		47
Sweet sucker		1				3		4
Black sucker		9			2	23		34
Hog sucker			1			7		8
White-nosed sucker		1				46		47
Common red horse			7	2	1	90		100
Short-headed red horse		1	1	12	1	57		72
Spoonbill cat							90	90
Totals	313	2986	317	579	712	1592	316	6815
	Fishes tagged in state fish hatcheries and miscellaneous other waters (large mouth black bass, channel cat, black crappies, white crappies, and bluegills							323
Grand Total -								7138

| Kind of fish | Mississippi River & Mississippi Bayous (above Mouth of Yazoo) | Lafourche Bayou & Southern Lakes | Rock Lake | Spoonbill Bayou | Deer Island | Lake Washington | Lake Pontchartrain | Lake Borgne | Bayou Terre aux Boeufs | Bayou Bienvenue | Bayou Dupre | Bayou Sauvage | Bayou Gentilly | Bayou St. John | Bayou Metairie | Bayou Grande Cote | Bayou Barataria | Bayou Lafourche | Bayou Terrebonne | Bayou Black | Lake Salvador | Lake Cataouatche | Lake Des Allemands | Bayou Des Allemands | Bayou Boeuf | Bayou Chene | Bayou Teche | Bayou Vermilion | Bayou Carlin | Bayou Plaquemine | Bayou Grand Caillou | Bayou Petit Caillou | Bayou Du Large | Bayou Du Large Island | Bayou Du Large Island | Bayou Du Large Island

Table III.—Summary of tags returned

Kind of fish	Number tagged	Number of tags returned			No. of days tags were carried (excluding those retaken by INHS	
		Hook and line fishermen	Commercial fishermen	INHS field party	Maximum	Average
Large mouth black bass	233	1(?)*			probably about 650	
Small mouth black bass	24					
Rock bass	76	2		1	6	4
Warmouth bass	36					
White bass	35	1			23	---
Yellow bass	21					
Black crappie	829	8	2	5	251	111
White crappie	926	4	3	10	117	51
Bluegill	404	2			108	56
Pumpkinseed	29			1		
Long-eared sunfish	10					
Green sunfish	5			1		
Garman's sunfish	1					
Wall-eyed pike	50			1		
Yellow perch	25	1			115	---
Pickerel	60	4		1	1174	686
Grass pike	1					
Sheepshead	214	1		1	(?)**	---
Eel	6					
Channel cat	524	2			620	326
Blue cat	1					
Flathead cat	88	5			1067	500
Black bullhead	719	5		10	277	79
Speckled bullhead	116			2		
Yellow bullhead	33					
Carp	1693	8	20	9	990	231
Red mouth buffalo	177		4	1	170	108
Mongrel buffalo	28					
Small mouth buffalo	49		1		8	---
Quillback	47		1	1	24	---
Sweet sucker	4					
Black sucker	34	2			159	159
Hog sucker	8					
White-nosed sucker	47					
Common red horse	100			1		
Short-headed red horse	72					
Spoonbill cat	90			2		
Totals	6815	46	31	47		

*A tagged fish, reported to be a 4-pound black bass, was taken at Elgin about May 10, 1932. The tag number was read incorrectly and the fish returned to the water.

**On Feb. 16, 1933 officers of the Iowa State Fish and Game Commission kindly forwarded a tag given them by an itinerant fisherman with the information that it was taken near Rockingham light on the Mississippi River about Aug. 16, 1932. This date is obviously incorrect since this fish was not tagged until Aug. 29, 1932. We have been unable to find the fisherman, one Earl Thompson.

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Table IV.—Migration of Illinois fishes

BLACK CRAPPIE

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
INHS 2798	Fox River	3 miles above Grass Lake.	July 12,1930	0.4	9.	downstream	222	W.R.Hamburger
INHS 3570	" "	Mouth of Indian Cr.	Sept. 8,1930	0.6	2.	downstream	29	E.E.Armstrong
INHS 4963	Illinois R.	Meredosia Bay	July 21,1931	0.55	0.5	in lake	2	I. N. H. S.
INHS 4964	" "	" "	July 21,1931	0.55	0.5	in lake	1.3	" " " "
INHS 4986	" "	" "	July 21,1931	0.7	0.5	in lake	0.4	" " " "
INHS 5454	" "	" "	July 31,1931	0.5	0.06	in lake	0.4	" " " "
INHS 5458	" "	" "	July 31,1931	0.5	3.3	in lake	13	" " " "
INHS 5761	" "	Big Lake Pumping Station.	Nov. 4,1931	0.3	12.	upstream	118	Tom Ganer
INHS 5979	" "	" "	Nov. 6,1931	0.55	12.	upstream	11	Oscar Kinney
INHS 6259	" "	" "	Nov. 6,1931	0.2	0.5	in lake	9	W. F. Condit
INHS 6284	" "	" "	Nov. 11,1931	0.6	6.	around island	28	M.L.Pontius
INHS 6344	" "	" "	Nov. 12,1931	0.6	77.	upstream	189	Gus Butsch
INHS 6347	" "	" "	Nov. 12,1931	0.5	1.5	downstream	251	Don Hughes
INHS 6523	" "	" "	Nov. 13,1931	0.4	1.	downstream	216	" "
INHS 6565	" "	" "	Nov. 16,1931	0.4	1.	downstream	34	Rex Hollenback

Table IV cont.—Migration of Illinois fishes

WHITE CRAPPIE

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
INHS 2104	Ohio River	Allard Lake	Apr. 3,1930	0.35	3.	in lake	43	Henry Morrow
INHS 2844	Fox River	McHenry	July 16,1930	0.3	none	---	1	I. N. H. S.
INHS 3562	" "	Mouth of Indian Creek,	Sept. 8,1930	0.5	2.	downstream	29	E.E.Armstrong
INHS 4686	Illinois R.	1 mile south of Havana.	May 11,1931	0.2	8.	upstream	17	John Lane
INHS 4942	" "	Meredosia Bay	July 17,1931	0.55	0.67	in lake	0.4	I. N. H. S.
INHS 5491	" "	" "	July 31,1931	0.4	0.06	in lake	0.4	" " " "
INHS 5492	" "	" "	July 31,1931	0.5	0.06	in lake	0.4	" " " "
INHS 5288	" "	" "	Aug. 7, 1931	0.3	0.5	in lake	.5	" " " "
INHS 5697	" "	Big Lake Pumping Station.	Nov. 4, 1931	0.5	2.	downstream	7	W. T. Boyd
INHS 5724	" "	" "	Nov. 4, 1931	0.35	1.	in lake	7	I. N. H. S.
INHS 5905	" "	North Lake	Nov. 5, 1931	0.4	16.	upstream	117	Tom Ganer
INHS 5907	" "	" "	Nov. 5, 1931	0.4	18.	upstream	117	" "
INHS 5964	" "	Big Lake Pumping Station.	Nov. 6, 1931	0.35	1.5	in lake	7	I. N. H. S.
INHS 5967	" "	" "	Nov. 6, 1931	0.4	1.	in lake	5	" " " "
INHS 5968	" "	" "	Nov. 6, 1931	0.25	1.5	in lake	11	" " " "
INHS 6703	Rock River	Above Gov't Dam, Sterling.	Apr. 19,1932	0.6	3.5	upstream	28	Charles Pippert
INHS 6943	Mississippi River	Wing dam above New Boston.	Aug. 17,1932	0.35	1.	downstream	1	I. N. H. S.

| | | |

Table IV cont.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
			WHITE BASS					
INHS 2827	Fox River	500 yds.above McHenry	July 16,1930	1.1	6.	upstream	23	F. J.Pechousek
			ROCK BASS					
INHS 2204	Fox River	Mouth of Nippersink Cr.	June 7, 1930	0.5	2.5	upstream	6	G. J. Vichman
INHS 2205	" "	" "	June 7, 1930	0.4	none	---	1	I. N. H. S.
INHS 2602	" "	Outlet of Pistakee L.	June 26,1930	0.4	1.	in lake	3	Bob Becker
			BLUEGILL					
INHS 2561	Fox River	Mouth of Nippersink Cr.	June 23,1930	0.6	8.	upstream	108	Otto Schuenemann
INHS 6779	Illinois R.	Senachwine L. Undercliff	June 21,1932	0.4	0.5	in lake	4	Leo Thompson
			PUMPKINSEED					
INHS 1509	Kaskaskia R	5 miles S.E. of Sullivan	Aug. 2, 1929	0.15	none	---	1	I. N. H. S.
			GREEN SUNFISH					
INHS 4741	Spoon River	3½ miles above mouth	May 28, 1931	0.3	0.06	upstream	2	I. N. H. S.

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
USBF 7333	Rock River	Fuller Farm below Rockford.	Mar. 12,1926	4.37	none	---	7	I. N. H. S.
USBF 7337	" "	" "	Mar. 12,1926	4.94	0.25	upstream	3	" " " "
USBF 7337	" "	" "	Mar. 15,1926	4.94	22.	downstream	750	John Eberley
USBF 7304	" "	" "	Mar. 15,1926	5.0	none	---	1	I. N. H. S.
USBF 7306	" "	" "	Mar. 15,1926	4.25	0.25	upstream	1	" " " "
USBF 7313	" "	" "	Mar. 15,1926	5.5	0.25	upstream	1	" " " "
USBF 7314	" "	" "	Mar. 15,1926	2.37	0.25	upstream	1	" " " "
USBF 7315	" "	" "	Mar. 15,1926	3.43	none	---	1	" " " "
USBF 7319	" "	" "	Mar. 15,1926	2.75	none	---	1	" " " "
INHS 633	Kaskaskia R.	3 mile below Carlyle.	Aug. 22,1929	2.3	0.5	upstream	264	E.L.Steinmann
INHS 160	" "	" "	Aug. 25,1929	1.8	20.	downstream	310	H. F. Hanke
INHS 133	Fox River	2½ mile above St. Charles.	Aug. 21,1930	2.0	0.5	upstream	30	Louis Nikodem
INHS 279	" "	1½ mile above Aurora dam.	Aug. 27,1930	4.35	1.	upstream	990	John Pasilis
INHS 517	" "	Mouth of Indian Creek,	Sept. 5,1930	5.5	none	---	663	Scott McCosh
INHS 529	" "	" "	Sept. 7,1930	1.5	none	---	1	I. N. H. S.
INHS 6082	Sangamon R.	Near Buck'sPond ab. Monticello.	Sept. 9,1930	1.4	3.	upstream	956	Wm. F. Lodge
INHS 6604	" "	" "	Sept. 9,1930	1.6	12.5	upstream	310	R. B. Head

Table IV cont.—Migration of Illinois fishes

CARP-continued

INHS 3693	Illinois R.	Upper Free Bridge, Peoria.	Oct. 22, 1930	2.6	3.5	downstream	112	Dixon Fisheries
INHS 3771	" "	" "	Oct. 23, 1930	2.3	3.5	upstream	51	" "
INHS 4024	" "	" "	Oct. 27, 1930	2.2	3.5	upstream	4	" "
INHS 4155	" "	Water Works Point, Peoria.	Nov. 5, 1930	1.6	none	---	1	" "
INHS 4218	" "	" "	Nov. 5, 1930	1.9	none	---	1	" "
INHS 4371	" "	Willow Point, Peoria	Nov. 12, 1930	2.2	7.5	downstream	91	" "
INHS 4431	" "	" " "	Nov. 12, 1930	2.0	2.	downstream	2	" "
INHS 3900	" "	Upper Free Bridge, Peoria	Nov. 18, 1930	2.1	3.	upstream	22	" "
INHS 5568	Spoon River	4 mi. above mouth.	Oct. 21, 1931	2.4	3.	downstream	349	Perry L. Barnes
INHS 433	Illinois R.	1½ mile below Grand Island.	Nov. 18, 1931	1.0	2.	downstream	32	Rex Hollenback
INHS 435	" "	" "	Nov. 18, 1931	1.7	8.7	" and into lake	272	Wm. LeTissier
INHS 446	" "	" "	Nov. 18, 1931	1.3	2.	downstream	18	Rex Hollenback
INHS 598	" "	" "	Nov. 18, 1931	1.6	5.	downstream	12	W. T. Boyd
INHS 664	" "	" "	Nov. 20, 1931	1.2	5.	downstream	59	W. T. Boyd
INHS 806	" "	Havana, Ill.	Jan. 21, 1932	4.8	2.5	downstream	106	Havana fisherman
INHS 965	" "	Undercliff B. L. Senachwine.	July 4, 1932	5.2	6.5	upstream	281	Milo B. Lock
INHS 7389	Mississippi R.	1½ mi. above Savanna	Aug. 24, 1932	2.7	7.5	downstream	222	V. Schumaker
INHS 7404	" "	" "	Aug. 26, 1932	2.1	1.5	upstream	202	" "
INHS 7430	" "	" "	Aug. 30, 1932	2.7	2.5	downstream	203	" "
INHS 7460	" "	2 miles below Clinton, Ia.	Sept. 20, 1932	1.2	2.	downstream	162	E. J. Petersen

Table IV cont.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	No. Days Tagged	Caught, or Reported by
			PICKEREL					
INHS 2297	Fox River	Pistakee Lake	June 19,1930	1.5	5.	in lake	360	F. H. Amos
INHS 2298	" "	" "	June 19,1930	0.8	1.	in lake	80	" " "
INHS 2863	" "	McHenry	July 16,1930	1.9	none	---	1	I. N. H. S.
INHS 2932	" "	"	July 22,1930	1.25	6.	upstream	1174	Clarence Yelk
INHS 932	" "	"	July 23,1930	2.2	0.75	downstream	1131	Robert Woldt
			YELLOW PERCH					
INHS 5832	Illinois R.	North shore of North L.	Nov. 4, 1931	0.65	1.5	---	115	Harold Butsch
			SHLEPSHEAD					
INHS 4754	Spoon R.	3½ miles above mouth	May 28, 1931	0.45	3.5	downstream	3	I. N. H. S.
INHS 7414	Miss. R.	1½ miles ab. Savanna	Aug. 29,1932	1.45	67.	downstream	?	Earl Thompson
			COMMON REDHORSE					
INHS 3433	Fox River	Mouth of Indian Cr.	Sept. 5,1930	0.9	.17	downstream	3	I. N. H. S.

Table IV cont.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	Time Tagged Days	Caught, or Reported by
			CHANNEL CAT					
INHS 33	Sangamon R.	2 miles above Monticello	July 16,1929	4.	4.	downstream	31	Edw. Pearson
INHS 3473	Fox River	Mouth of Indian Cr.	Sept. 6,1930	1.	1.	downstream	620	John Dummett
			FLATHEAD CAT					
	Sangamon R.	1½ mi. above Monticello	July 13,1929		3.5	downstream	36	Edw. Pearson
INHS 11	" "	"	July 13,1929	7.3	28.	downstream	1067	Elmer O. Good
	" "	"	July 13,1929		8.	upstream	322	Fred Cox
INHS 7	" "	"	July 13,1929	12.1	30.	downstream	332	Elmer O. Good
INHS 24	" "	2 mi. above Monticello	July 15,1929	8.2	16.	downstream	745	" " "
			SPECKLED BULLHEAD					
INHS 2656	Fox River	Head of Grass Lake	July 2,1930	0.4	none	---	1	I. N. H. S.
INHS 2658	" "	" "	July 2,1930	0.4	none	---	1	" " " "

Table IV cont.--Migration of Illinois fishes

BLACK BULLHEAD

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	Time Tagged Days	Caught, or Reported by
INHS 1093	Sangamon R.	2 mi. above Monticello	July 13,1929	0.3	none	---	1	I. N. H. S.
INHS 1174	" "	Above Springfield dam	July 25,1929	0.2	0.25	upstream	2	" " " "
INHS 1340	" "	Decatur Disposal Plant	Aug. 18,1929	0.2	0.01	downstream	1	" " " "
INHS 1359	" "	" "	Aug. 18,1929	0.25	0.01	downstream	1	" " " "
INHS 2313	Kaskaskia R.	2 mi. above mouth	Feb. 26,1930	0.5	15.	upstream	18	A.J.Nabelrath
INHS 2324	" "	" "	Feb. 26,1930	0.5	15.	upstream	18	" " "
INHS 2336	" "	" "	Feb. 26,1930	0.4	none	---	1	I. N. H. S.
INHS 2406	" "	" "	Feb. 27,1930	0.25	none	---	1	" " " "
INHS 2408	" "	" "	Feb. 27,1930	0.2	none	---	1	" " " "
INHS 2411	" "	" "	Feb. 27,1930	0.25	15.	upstream	17	A.J.Nabelrath
INHS 2464	" "	" "	Feb. 28,1930	0.45	none	---	1	I. N. H. S.
INHS 2470	" "	" "	Feb. 28,1930	0.35	28.	upstream	63	C. H. Kruse
INHS 2473	" "	" "	Feb. 28,1930	0.3	none	---	1	I. N. H. S.
INHS 2485	" "	" "	Mar. 1,1930	0.3	2.	upstream	2	" " " "
INHS 5238	Illinois R.	Meredosia Bay	Aug. 5,1931	0.8	5.	in lake	277	Theo. C. Coe

| | | |

Table IV concl.—Migration of Illinois fishes

Tag Number	Stream	Location	Date	Wgt., Lbs.	Water Distance Miles	Migration Direction	Time Tagged Days	Caught, or Reported by
			RED MOUTH BUFFALO					
USBF 7258	Rock River	Winnebago Co. Farm	Feb. 26,1926	2.06	2.5	downstream	37	W. H. Denton
INHS 356	Illinois R.	Upper Free Bridge,Peoria	Oct. 21,1930	2.5	46.	downstream	170	Dixon Fisheries
INHS 4336	" "	" "	Nov. 11,1930	2.8	3.5	upstream	138	Dixon Fisheries
INHS 4505	" "	Andy Gowan's Point	Nov. 14,1930	2.3	10.	upstream	86	William Todd
INHS 6264	" "	Big Lake Pumping Sta.	Nov. 6,1931	0.5	0.5	in lake	4	I. N. H. S.
			SMALL MOUTH BUFFALO					
INHS 360	Illinois R.	Upper Free Bridge,Peoria	Oct. 21,1930	2.5	3.	upstream	8	Dixon Fisheries
			QUILLBACK					
USBF 7254	Rock River	Winnebago Co. Farm	Feb. 26,1926	1.87	2.5	downstream	24	W. H. Denton
INHS 4746	Spoon River	3½ mi.above mouth	May 28,1931	1.0	0.5	upstream	2	I. N. H. S.
			BLACK SUCKER					
INHS 3282	Fox River	1 mile above Aurora Dam	Aug. 27,1930	1.0	3.5	downstream	159	J. A. Sayer
INHS 3283	" "	" "	Aug. 27,1930	1.05	3.5	downstream	159	" " "

The carp, Cyprinus carpio L., furnished the largest series of returns. In Table V, p. 18, the 37 carp returns are divided into five convenient time periods and the migration constant is calculated for each. In contrast with the similarity of these calculated migration constants, the average distance per day varies widely, as may be seen in the last column.

Since the number of returns on other single species of fish is insufficient for statistical uses, I have lumped the data from all of the basses, crappies, and sunfishes—the so-called "fine fish." It may be seen in Table I that all of these have similar calculated rates of migration. These data have been arranged in three different time periods in Table VI, p. 19, where it may be seen that the calculated migration constants are more uniform than the average distances per day.

To determine whether fishes of different sizes migrate at different rates, the 37 returns from carp, which ranged from 1 to 5½ pounds, have been divided, in Table VII, p. 20, into four weight classes. The migration constants for these four weight classes vary from 0.23 to 0.66 but it is not considered that these numbers indicate any real differences in rate of movement between carp of different sizes.

In Table VIII, p. 20, these 37 carp have been divided according to streams, and migration constants calculated. The data on some of these streams are too fragmentary to be of much significance, but the returns from Fox River carp are sufficiently complete, and diverge from those of other streams so widely, that it seems certain that carp do migrate shorter distances there than in other streams. The reason for this lack of extensive migration in the Fox River is obvious since it is crossed at many points between McHenry and the mouth by dams. These dams are high enough to prevent fish going upstream at any time except during very high floods, and from going downstream, unless they go through the turbines or over the tops of the dams at flood stage. Furthermore the river was so low throughout 1930 and the years succeeding that carp are for the most part restricted to the pools immediately above these dams.

For 15 years the carp of the upper and middle Illinois River have exhibited an unusual abnormality referred to by local fishermen as "knothead" carp. We have learned that the knothead abnormality is caused during the early life of the carp by certain pollutional conditions which existed in the Illinois River. In the winter of 1926-27 when a detailed study of the knothead abnormality was made in the Illinois River, it was found that approximately 90 per cent of the carp from Peoria Lake and points upstream, showed abnormality in greater or smaller degrees.

Table V.—Migration rate of carp, bearing tags varying lengths of time*

	Number of tags returned	Total number of days	Total number of miles	Rate of migration in miles per day: Calculated as water distance in miles divided by the square root of the number of days, and weighted by the number of days the tags were carried.	Rate of migration in miles per day: Average distance in miles per day.
Tagged 1-10 days	13	25	6.5	0.44	0.26
" 10-50 days	5	114	12.5	0.47	0.11
" 50-200 days	6	581	24.0	0.38	0.04
" 200-400 days	9	2413	62.7	0.44	0.03
" 400 or more	2	1706	25.0	0.41**	0.01
Total	35	4839	130.7	Carp migration constant	0.42

*Since this paper was written, Dr. A. H. Hersh has brought to my attention D'Arcy Thompson's account (Growth and Form, p. 47) of the simulation of Brownian movement by the activities of living things "....Following with a pencil the track of each little swimmer and dotting its place every few seconds (to the beat of a metronome), Karl Przibram found that the mean successive distances from a common base-line, obeyed with great exactitude the 'Einstein formula,' that is to say the particular form of the 'law of chance' which is applicable to the case of the Brownian movement..."

**This figure does not include two carp from the Fox River which bore tags for 990 and 663 days, respectively. Due to numerous dams, and to prevailing low stages of water since 1930, the movements of these two carp were restricted to the pools above the Dayton and Aurora dams in which they were tagged. When they are included this figure is reduced to 0.22.

	15	En	6.5		
	8	114	12.3	0.47	0.12
	5	891	74.0	0.38	0.02
" 300-400 days	9	2412	58.7	0.64	0.08
		1706	28.9	0.41**	0.21
Total	85				

Table VI.—Migration rate of "fine fish,"—basses, sunfishes, and crappies, bearing tags over various periods of time.

	Number of tags returned	Total number of days	Total number of miles	Rate of migration in miles per day	
				Calculated as water distance in miles divided by the square root of the number of days and weighted by the number of days the tags were carried.	Calculated as average distance in miles per day.
Tagged 1-20 days	25	116.3	26.5	1.02*	0.33*
" 20-150 days	11	674	77.5	1.05	0.11
" 150 or more	4	878	88.5	1.41	0.10
Total	40	1668.3	192.5	"Fine fish" migration constant	1.24

*These figures are increased to 1.56 and 0.46 respectively when the 18 returns by I. N. H. S. are excluded. Since much of our fishing was done in restricted areas, these returns, while not covering more than a few days, do not give a fair measure of the migrations of such relatively fast moving fishes.

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Table VII.—Migration rate of carp of different weights

Weight in pounds	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
1.00 - 1.65	9	1551	31.5	0.27
1.65 - 2.25	9	934	46.7	0.66
2.25 - 4.00	9	1204	20.75	0.23
4.00 - 5.50	8	1150	31.75	0.64*

*This figure is decreased to 0.27 when the two carp from the Fox River are included which bore tags 990 and 663 days.

Table VIII.—Migration rate of carp in different Illinois streams

River	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
Mississippi	4	789	13.5	0.25
Illinois	15	1064	54.7	0.48
Rock	9	766	23.0	0.79
Kaskaskia	2	574	20.5	0.63
Sangamon	2	1266	15.5	0.25
Fox	4	1684	1.5	0.02
Spoon	1	349	3.0	0.16

Carp from Havana and points downstream showed no abnormality, excepting for a few individuals, perhaps one in a hundred, which supposedly had straggled downstream from Peoria Lake. At points between Peoria and Havana, intermediate percentages of "knothead" carp were found. At Pekin, for example, about 30 per cent of the knothead abnormality occurred. These percentages were based on carp averaging about 5 years of age, hence it seemed clear that carp did not migrate any considerable distances in the five years from the time the knothead characteristic was determined in the fry stage until they were caught 5 years later, else the dividing line between knothead and normal carp would not be so clear-cut as it is between Peoria and Havana. Table I shows that the calculated average migration of a carp in five years is 17.9 miles. This figure was rather accurately predicted from a consideration of the distribution of knothead and normal carp in the Illinois River.

The data on tagged carp have been arranged in Table IX, p. 22, to show the rates of upstream and downstream migration. The rate of upstream migration shows a calculated migration constant of 0.24 miles in one day, while the downstream rate is 0.57 miles per day. I regard these rates as significantly different. The greater downstream rate may be a reflection of the effects of drouth since fishes commonly exhibit an optimal stream size and move downstream in times of drouth. The data on tagged "fine fish" show upstream movements almost ten times as rapid as downstream. The reason for this difference from the behavior of carp is not clear. It may be supposed that "fine fish," most of which are found in bottomland lakes and other quiet waters, travel upstream willy-nilly when they find themselves in a current. Their rate of migration in lakes is only one-fourth their upstream rate. It must be remembered that any fish which shows a preferential downstream movement under all conditions cannot long remain an Illinois fish and leave descendants to inhabit Illinois waters. Since these "fine fish" are not typical stream fishes, their reactions may be imperfectly adapted to stream life. This view seems to be supported by the low rates of migration found for typical stream fishes such as channel cat, common redhorse, black sucker, carp, and quillback. It appears that typical stream fishes are those which have a set of reactions which allow them to hold their place in a stream without crowding into the headwaters or being swept down to sea.

While the evidence obtained by analysis of statistics presented here shows that the movements of fishes are random in nature, it is not incompatible with many kinds of observations which show that the movements of fishes are directed, i. e., not random. These seemingly opposite views may be readily harmonized by supposing that this randomness of fish movement appears only as a gross relationship covering long periods of time, while those observations tending to show that fish movements are directed commonly apply to much shorter periods of time. A great number of physical variables in water affect the movements of fishes,

Table IX.—The rates of upstream and downstream migrations of carp

Direction of migration	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
Upstream	13*	2126	35.5	0.24
Downstream	15	2700	95.2	0.57
Standstill	7**	13	--	--

* One carp which traveled upstream one mile in 990 days has been omitted because its movements were restricted to the pool above the Aurora dam.

**This excludes one carp which carried a tag 663 days and was retaken at the same place it was tagged in the pool above the Dayton dam on Fox River.

Table X.—The rates of upstream and downstream migrations of basses, sunfishes, and crappies,—so-called "fine fish"

Direction of migration	Number of tags returned	Total number of days	Total number of miles	Calculated rate of migration in miles per day
Upstream	11	736	163.06	2.41
Downstream	8	789	19.5	0.26
In lake	18	140.3	22.15	0.58
Standstill	3	3	---	--

and these are interrelated in so complex a manner, and exist in such a constant state of flux, that no one factor is of sufficient importance or persists over a long enough period of time to produce marked variations from the appearance of randomness.

For example, it is well known that fishes move upstream in spring during times of heavy rainfall and floods. Conversely, they move downstream during summer and fall when streams are shrunken and suffer from drouth. This movement exists because most kinds of fishes prefer a stream of a certain size, some great and some small. When rains cause an increase in the volume of water, the fishes tend to move upstream until they find their optimal stream size. When drouth causes a shrinkage they tend to drift downstream until they find this same optimal stream size.

In winter, the Illinois River is occasionally covered with ice for periods of several weeks which halts the natural reaeration of the water and in the presence of pollution causes a deficiency of dissolved oxygen. Under such conditions fish are seldom killed unless they are caught in nets or are otherwise trapped and cannot escape suffocation. At such times they congregate in the mouths of tributary streams or crowd into "spring holes" which do not freeze. Observations at such times indicate that the fish do not blunder into the mouths of these tributaries and into "spring holes" but are guided to them by following slightly increasing amounts of dissolved oxygen from points downstream.

In the summer of 1931, while fishing in Meredosia Bay with fyke nets, near the mouth of a long narrow slough, we learned that on a certain night the dissolved oxygen in this water fell below the critical concentration and the fishes of this slough moved out into the bay in a body. We learned also that when fishes become embarrassed from lack of oxygen their movements are more rapid than at other times. Such a reaction tends to carry them over wider areas and will more probably bring them into higher concentrations of oxygen if such exist in the vicinity.

During autumn the fishes of certain of our swifter streams, such as Rock River, gradually accumulate in the eddies and quieter pools. By midwinter almost the entire fish population of the stream may be found in pools and eddies which make up only a few per cent of the total area of the stream. When the water warms in spring they leave these quiet spots and scatter until they may be found in about equal abundances in all velocities of water. This behavior, too, is essentially random in nature, since as the water cools the swimming movements of the fishes become so slow that they can no longer stem the current. Then they drift tail foremost downstream until they find water so quiet they can hold their position even though numbed by ice cold water.

Evidence that the movements of individual fishes are not completely independent of each other is furnished by certain fish tag returns. On February 26 and 27, 1930, Mr. Hunt tagged and released 99 black bullheads 2 miles above the mouth of the Kaskaskia River. On March 16, 1930 Mr. A. J. Nabelrath caught three of these tagged bullheads while fishing in Dooley Lake in the Kaskaskia bottomlands, 15 miles upstream. It is clear that these bullheads congregate into schools and travel together, since the possibility of three fishes being caught on the same day and at the same place after having traveled 15 miles by random movement is so remote that it may be regarded as outside the realm of experience.

If fishes moved in a strictly random manner it would be necessary for them to travel, during short periods of time, at velocities much higher than the observed velocities to make possible the daily rates given in Table I. For example, carp which are 0.42 mile distant after one day are calculated to move 7.5 feet in one second were their motions strictly random. In the same way "fine fish" with a daily migration of 1.24 miles are calculated to have a displacement of 22.3 feet in 1 second. The observed rates over such short periods of time are much slower than these calculated rates. A carp may swim at the rate of 7.5 feet per second during bursts of speed, but none of our fish can reach speeds of 22.3 feet per second. This divergence of the observed rates from the calculated rates is due to the fact that the movements of fishes are directed over short periods of time by environmental influences and due to the fact that a fish swims head foremost and is guided as if by a rudder. Direct observations of the movements of fishes show that they frequently spend considerable time in one place, or within a very circumscribed area, and then move rather directly to another place, several or more yards away. Here they may again hesitate and "mill around" for a time, and then proceed either leisurely or in a rather business-like manner in some other direction. The rate of these movements from place to place seldom exceeds more than 1 or 2 feet per second unless the fishes are frightened or are pursued.

feet per second unless the flames are lengthened or are curved.

RELATIVE GROWTH IN POLYODON

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STATE OF ILLINOIS
Department of Registration and Education
Division of the
NATURAL HISTORY SURVEY
Theodore H. Frison, Chief

BIOLOGICAL NOTES NO. 2 URBANA, JANUARY 1, 1934

Relative Growth in Polyodon

David H. Thompson

Rostrum.—The spoonbill cat, Polyodon spathula (Walbaum), has a broad, thin, paddle-shaped rostrum of cartilage enclosed in a loose network of bony splints. This great rostrum with its many sensory endings serves for the detection of plankton and other small organisms on which this fish feeds. The mouth is unusually large and the gill arches are furnished with numerous long gill rakers which strain out the food organisms as the fish swims about with its mouth open. It swims unceasingly with a monotonous rhythm and swings the rostrum from side to side in a wide arc. It has been supposed that these movements of the rostrum are of use in beating small animal life from vegetation in weedy lakes, but there is no evidence of any active digging.

Distribution.—Polyodon inhabits the Mississippi River, its connecting bottomland lakes and bayous, and the lower courses of its larger tributaries, including the Ohio, the Missouri, and the Illinois. It is a ganoid and resembles the sturgeons more than it does other native fishes. It has only one living near relative, Psephurus gladius, a large fish found in the Yangtze River in China. A fossil form, Crossopholis magnicaudatus, has been described by Cope (1883, 1885, 1886) from the Eocene Green River shales in Wyoming. Fossils of two specimens about a meter in length show snouts shorter than those of the two living forms (Dean, 1895).

Measurements.—In May, 1932 we collected seven larval specimens of Polyodon (Thompson, 1933) from which the length of rostrum and of body were measured. Extensive series of such measurements are given by Stockard (1907) and Danforth (1911). Barbour (1911) figured three specimens which have been measured, and Doctor N. Borodin has kindly furnished me measurements of three very small specimens in the Museum of Comparative Zoology at Harvard. Nichols (1916) published the measurements of a very large individual. These have been supplemented by measurements of other specimens in the collections of the Illinois Natural History Survey. Since these data form an unusually complete series, they show in some detail the relation between the length of rostrum and the length of body. This comparison of relative growth is of especial interest, since the rostrum is relatively very small in larvae, relatively greatest in specimens about 250 millimeters long, and becomes relatively shorter in larger individuals. The data are especially significant since the range of sizes is very great, the largest specimen being 127 times as long as the smallest specimen. Throughout all these sizes the spoonbill is free living, has no abrupt metamorphosis, inhabits the same waters, and feeds on the same food.

The following tabulation shows these measurements arranged in order of increasing total lengths. The rostrum and body

Polyodon Measurements

Sources	Total length	Length of rostrum to front of eye	Length of body from front of eye	Rostrum as per cent of body length
	mm.	mm.	mm.	
Ill. Nat. Hist. Surv.	17.0	1.5	15.5	9.7
" " " "	17.5	1.2	16.3	7.4
" " " "	18.5	1.5	17	8.8
" " " "	19	1.6	17.4	9.2
" " " "	19	1.7	17.3	9.8
" " " "	20	1.7	18.3	9.3
" " " "	20	1.8	18.2	9.9
Borodin	37	8	29	27.6
"	57	15	42	35.7
"	60	19	41	46.3
Danforth	74	22	52	42.3
Barbour	80	24	56	42.9
Danforth	89	26	63	41.3
"	104	34	70	48.6
"	107	34	73	46.6
Barbour	130	46	84	54.8
Danforth	140	48	92	52.2
"	144	49	95	51.6
"	170	58	112	51.8
"	175	58	117	49.6
"	200	78	122	63.9
Ill. Nat. Hist. Surv.	200	69	131	52.7
" " " "	212	71	141	50.4
" " " "	215	69	146	47.3
" " " "	220	71	149	47.7
" " " "	225	78	147	53.1
" " " "	226	80	146	54.8
" " " "	227	82	145	56.6
" " " "	229	75	154	48.7
" " " "	230	79	151	52.3
" " " "	233	78	155	50.3
" " " "	233	83	150	55.3
" " " "	235	82	153	53.6
" " " "	240	89	151	58.9
" " " "	241	77	164	47.0
" " " "	248	83	165	50.3
" " " "	250	92	158	58.2
" " " "	252	88	164	53.7
" " " "	255	87	168	51.8
" " " "	261	89	172	51.7
" " " "	263	92	171	53.8
" " " "	266	85	181	47.0
" " " "	267	89	178	50.0
" " " "	270	92	178	51.7
" " " "	277	102	175	58.3
" " " "	309	113	196	57.7

Polyodon Measurements—continued

Sources	Total length	Length of rostrum to front of eye	Length of body from front of eye	Rostrum as per cent of body length
	mm.	mm.	mm.	
Ill. Nat. Hist. Surv.	410	131	279	47.0
" " " "	453	155	298	52.0
" " " "	514	152	362	42.0
" " " "	515	173	342	50.6
" " " "	526	177	349	50.7
" " " "	528	177	351	50.4
" " " "	531	180	351	51.3
" " " "	540	175	365	47.9
" " " "	543	160	383	41.8
" " " "	558	185	373	49.6
" " " "	577	188	389	48.3
Stockard	610	203	407	49.9
Ill. Nat. Hist. Surv.	621	199	422	47.2
" " " "	632	197	435	45.3
" " " "	752	236	516	45.7
Stockard	762	229	533	43.0
"	914	259	655	39.5
Barbour	914	245	669	36.6
Danforth	1,000	260	740	35.1
"	1,030	290	740	39.2
"	1,050	310	740	41.9
"	1,070	260	810	32.1
"	1,090	300	790	38.0
Stockard	1,118	305	813	37.5
Danforth	1,180	320	860	37.2
"	1,200	340	860	39.5
"	1,210	330	880	37.5
"	1,210	310	900	34.4
Stockard	1,245	333	912	36.5
"	1,295	343	952	36.0
Danforth	1,300	330	970	34.0
Stockard	1,346	343	1,003	34.2
"	1,499	356	1,143	31.1
"	1,524	404	1,120	36.1
"	1,575	406	1,169	34.7
"	1,600	400	1,200	33.3
"	1,600	419	1,181	35.5
"	1,676	400	1,276	31.3
"	1,702	432	1,270	34.0
"	1,753	454	1,299	34.9
Nichols	2,159	432	1,727	25.0

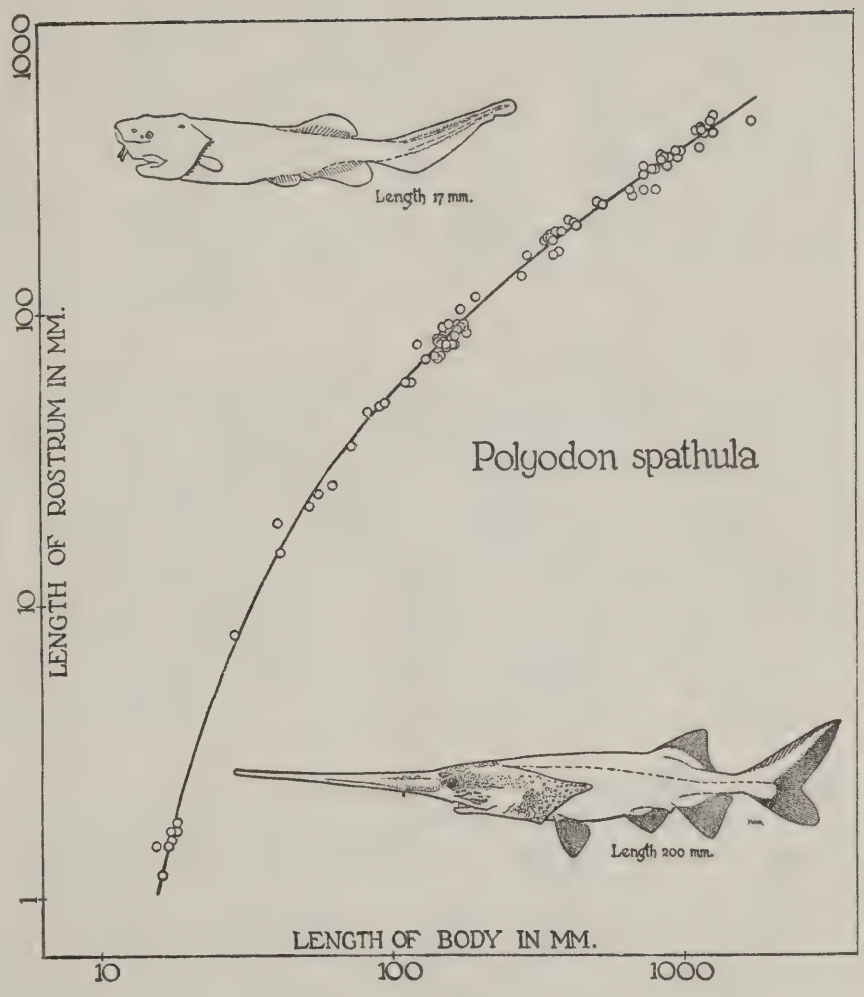
were measured from the front edge of the eye in order to be able to include published measurements. The eye is a well-defined base of reference for measurements in fishes and is particularly useful in growth studies since it is differentiated very early and is firmly anchored in the chondrocranium.

Differential growth.—In the accompanying figure, p. 5, the measurements of the length of rostrum are plotted against those of the length of body using the same logarithmic scale. An examination of the distribution of these points suggests a curve rather than a combination of two or three straight lines. Huxley (1932) has described a number of relative growth curves in which one straight line breaks abruptly into another straight line with a different slope. He also shows instances in which one straight line breaks into another through a short curve. May it not be that all such relative growth curves are hyperbolas with asymptotes crossing at varying angles and approaching these asymptotes more or less closely? It appears from inspection that the Polyodon measurements lie on an hyperbola whose asymptotes cross at an angle of about 135 degrees. A smoothed curve has been drawn by selecting the point where curvature is greatest and by drawing a symmetrical curve to the rather straight limbs at either end. The upper end of the curve, representing measurements of the larger specimens, is almost straight with a slope of 0.68. The lower end has a slope of about 4.1.

In order to learn something about the distribution of this differential growth within the rostrum of Polyodon, the length from the barbel to the eye was plotted against body length. This region was found to grow at the same rate as the body. Therefore, from the standpoint of relative growth, this part between the barbel and the eye will be considered as part of the body, since all of the heterogonic growth occurs in the part distal to the barbels.

The distance from the posterior edge of the eye to the tip of the opercular flap was measured on the specimens in the collections of the Illinois Natural History Survey and combined with other measurements made in the same way by Danforth (1911). When the logarithm of this length is plotted against the logarithm of body length one obtains a curve of heterogonic growth similar to that for the rostrum except that it shows smaller departures from isogonic growth. The slope of the lower limb of the operculum curve is about 1.9. It reaches a value of 1 at about the same body size as does the rostrum curve, and then declines slightly.

Barbel length was also measured throughout a wide range of sizes of spoonbill. When the logarithm of the length of barbel is plotted against the logarithm of length of body it may be seen that its relative rate of growth is at all times slower than that of the body within the size range of fishes used. The barbel curve begins with a slope of 0.7 but, in body lengths exceeding 100 millimeters, it has a slope of only 0.3. It should be mentioned that the barbel, like the rostrum and the opercular flap, is


1000
100
10
1
LENGTH OF ROSTRUM IN MM.
Length 17 mm.
Polyodon spathula
Length 200 mm.
LENGTH OF BODY IN MM.
10
100
1000

made up essentially of cartilage and skin. I should like to emphasize that the rostrum, the opercular flap, and the barbels each show declining rates of growth relative to the rest of the body.

Discussion.—Assuming an earlier stage in the development of Polyodon than has yet been discovered, a stage in which recognizable rudiments of the rostrum, opercular flaps, and barbels have not been differentiated, and keeping the relative growth curves of these organs in mind, an examination of the 17 millimeter specimen suggests that the barbels are differentiated first and go through an initial period of rapid development followed by declining growth rates relative to the rest of the body. Subsequently, the rostrum and opercular flaps are differentiated and grow at high initial rates which decline to the rate of the rest of the body or lower. Since barbels, opercula, and the rostrum each originate from cells, or groups of cells, with the capacity for synthesizing cartilage, it seems likely that the growth histories of these organs may be expressed as an equilibrium reaction between the total amount of growing cartilage in these organs and the concentration of cartilage-forming substances in the blood stream which feeds this cartilage.

Polyodon feeds on the same food throughout its life. Hence, it may be supposed that the digestive and assimilative processes remain the same throughout its life and, under comparable environmental conditions, that the amount of cartilage-forming substances put into the blood stream is closely proportional to the size of the body. Thus, we may expect that the actual concentration of these hypothetical cartilage-forming substances in the blood stream is greater in early stages of development, when there is little or no cartilage, than in later stages when there is relatively much cartilage to use them up by its mere subsistence. The rate of growth of these cartilaginous parts may then be expected to decline to the rate of the rest of the body.

While the assumption of an unutilized excess of cartilage-forming substances may account satisfactorily for the high initial growth rates of rostrum, barbels, and opercular flaps, and for the subsequent decline in the relative growth rate of these parts, it must be modified to account for the fact that the barbel curve has a slope of 0.3 in the same fishes which show rostrum and operculum slopes of approximately 1. In order to account for such differences in relative growth rates we may suppose that there are intrinsic differences in their component cells as regards their rate of multiplication, and since the barbels are attached to the rostrum, we may suppose that these intrinsic differences arise by some process akin to starvation. The same sort of explanation may be used to account for the decline in the rate of growth of the rostrum below that of the rest of the body. Polyodon shows an increasing proportion of rostrum until the fish has a total length of about 250 millimeters after which the proportion of rostrum declines. It has already been mentioned that the heterogonic

growth of the rostrum is limited to its distal part. One may look on this distal part as a growing tip—that there is isolated in the tip of the snout of a spoonbill larva a cell, or group of cells, which grow more rapidly than do those of the remainder of the animal; furthermore, that this cell, or group of cells, is carried forward by its own growth leaving behind it cell descendants which grow at the same rate as the rest of the body, i.e., more slowly. Since this growing tip apparently has the capacity to produce cartilage at a greater rate than its cell descendants in the same concentrations of cartilage-forming stuffs, it will tend to build up a surplus which cannot be maintained at an isogonic growth level once this growing tip is destroyed or is changed in its growth potentialities. As the gross amount of the cell descendants of this growing tip increases relative to the rest of the body, the blood supply reaching the tip must traverse more and more cartilaginous tissue and hence may become poorer and poorer in cartilage-forming substances. It seems reasonable that this starvation will reach a point where the growing tip is either destroyed altogether or is so altered that its cells no longer multiply more rapidly than those of other parts of the rostrum.

As one inspects the outstanding anatomical features of Polyodon in the material which we have available, it is apparent that the rostrum and the opercular flaps are the last organs to be differentiated. All other organs and major parts already have made their appearance and have passed through the initial stages of their growth history. We should look upon the heterogonic growth of the rostrum and the operculum as the normal growth behavior of parts which have been delayed in their differentiation while other large organs of the body have already been differentiated and have come into growth equilibrium with each other.

The rostrum is in a variable and unregulated condition. It may be looked upon as an organ which has been recently evolved and not yet coordinated with the rest of the body, or else, while it may be quite old, it has not been subjected to rigorous selective action. As one compares a series of specimens of Polyodon of the same body length one finds that such anatomical features as body contour, length, width, and insertion of fins, size of eye, and expanse of mouth are very uniform and fixed in their proportions. In contrast with the fixity of these morphological features the length of rostrum varies widely. It is apparent, however, that individuals with short rostra show a compensating increase in width. The lengths of opercular flaps not only vary from fish to fish but are usually different on the right and left sides. The rostrum of the spoonbill, as compared with the snouts of other fishes, may be considered as an organ which has undergone great changes since the ancestors of Polyodon split off from other fishes, and is twice as large as that of the Eocene spoonbill, Crossopholis.

The sturgeons are the nearest living relatives of the Polyodontidae, and, since sturgeons have snouts about the same size as that portion of the Polyodon snout between the barbel and the eye (which we have already shown grows at the same rate as the rest of the body) we may look on the remainder of the Polyodon rostrum as something added to the essential organization of a sturgeon-like fish. Since this added part appears late in development and is recognizable only insofar as it grows faster than the rest of the body, it may be considered as a sort of benign tumor which has become partially fixed in its characteristics and is in some degree useful as a bearer of sense organs for the detection of food. Like a tumor it may be removed without seriously hampering the welfare of the individual since we have found a number of specimens with various fractions of the rostrum cut off and healed over, as far back as the barbels.

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THE AUTOMOBILE AND PRAIRIE WILD LIFE

W. P. Flint

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Department of Registration and Education
NATURAL HISTORY SURVEY DIVISION
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Biological Notes No. 3 Urbana, July 20, 1934

THE AUTOMOBILE AND PRAIRIE WILD LIFE

W. P. Flint

THE death toll that the automobile takes of wild life on the Illinois prairie may be more of a benefit than a loss to man. Two thirds of the animals found dead on a section of state highway in a three year count taken by the Illinois State Natural History Survey, were from the human standpoint more or less undesirable.

These conclusions proceed from a series of records kept from May 1, 1930 to December 31, 1932, on a 25 mile stretch of state highway 10 between Urbana and Oakwood, Illinois. This east and west concrete road is typical of central Illinois and connects Danville, a city of more than 36,000, with Champaign-Urbana, a little larger and home of the state university.

The road passes through four towns of 100-800 population and close by two more of the same size. Most of it is over level prairie and through a fertile farming area. Two streams are crossed, the Salt Fork at St. Joseph and Stoney creek near Oakwood. Several pieces of woodland are near the road but not intercepted. The Illinois Traction system and the Peoria branch of the Big Four railroad closely parallel the highway most of this distance.

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Average speed of the moderately heavy traffic is 35-50 m.p.h. In summer 80-100 cars will be met in driving this stretch of 25 miles, and in winter the number varies between 40 and 80. Counts made on a number of separated days show that from early morning until late evening about two cars each minute pass over a given section of this highway.

Records of the accompanying tables were for the most part made on Sunday mornings between seven and nine, though occasionally in the afternoon or on other days. There was at least a five day interval, and in most cases a seven day wait, between the recordings. Two persons rode in the car at a rate of 20-25 m.p.h. At higher speed many of the small birds are overlooked. Whenever a dead animal or bird was not readily identifiable the car was slowed or stopped. Even so 22 animals and 66 birds remain unknown for the three years of observation, due mainly to the mangled and decomposed state in which they were found.

In those three years the observers found 1006 animals dead on the highway, in a total of 2100 miles, or an average of one animal or bird killed by an automobile every two miles. The greatest group was as might not be expected, 448 English sparrows, followed by 118 gophers and 84 chickens. In all, 32 kinds of animals or birds met their death on this highway, 10 of them being found only once.

One of the most significant facts in connection with this survey is the uniformity in numbers of the animals killed each year. It is also evident that most of them are killed from April to October. The length of time a body remains on the highway was found to be rarely more than three days. In most cases it does not remain more than a day but occasionally may become stuck to the highway and stay there a week or more.

A familiar sight is one or more crows feeding on carcasses, either in the road or at the side to which they have dragged them. As they feed mostly in early morning few animals had been removed by them before the counts were made.

The only game animal killed in any number is the rabbit. The killing of cats is to be regarded generally as beneficial since they are notorious destroyers of birds and small game. Song and insect-eating birds are not appreciably reduced by the automobile. Blackbirds, cats, gophers, mice, rats and sparrows, all undesirable, comprise 68.4 per cent of the animals found dead on the highway during these three years.

It is to be acknowledged that the data give a very local picture, but it is considered to be typical of the region. The faunal change would vary with latitude and topography, but there is reason to believe that the effect of the automobile on our wild life is much less detrimental than formerly supposed.

Dr. M. D. Farrar, research entomologist, and Mrs. Flint assisted in collecting the data.

TABLE I

DEAD ANIMALS ON A 25 MILE STRETCH OF ILLINOIS HIGHWAY

May 1, 1930 to December 31, 1930.

	Month	May	June	July	Aug.	Sept.	Oct.	Dec.	Total
	No. of Observations	4	4	4	4	2	1	1	20
	Animal or bird								
1	Blackbird	1							1
2	Cat	2		1	6		1		10
3	Chicken	6	4	5	11	3	1	1	31
4	Flicker	2		1	2				5
5	Gopher	10	7	3	10	5	2		37
6	Meadowlark	1	1	1					3
7	Mouse		1						1
8	Muskrat		1						1
9	Owl						1		1
10	Rabbit	4	4	7	4	1		2	22
11	Rat		1		1	1			3
12	Redheaded Woodpecker	2	1	2	2				7
13	Robin	1							1
14	Skunk	1				1			2
15	Snake	1				4			5
16	Sparrow (English)	9	23	45	59	6	2	2	146
17	Squirrel					1		1	2
18	Thrasher		2	1	1				4
19	Toad			1					1
20	Turkey	1							1
21	Turtle	1	2						3
22	Animals Unknown	1	1	4	4	2			12
23	Birds Unknown	2	7	3	6				18
	Total	44	55	74	106	24	7	7	317
	No. of Miles	100	100	100	100	50	25	25	500
	Average No. of Animals per Mile	.44	.55	.74	1.06	.48	.28	.28	.634

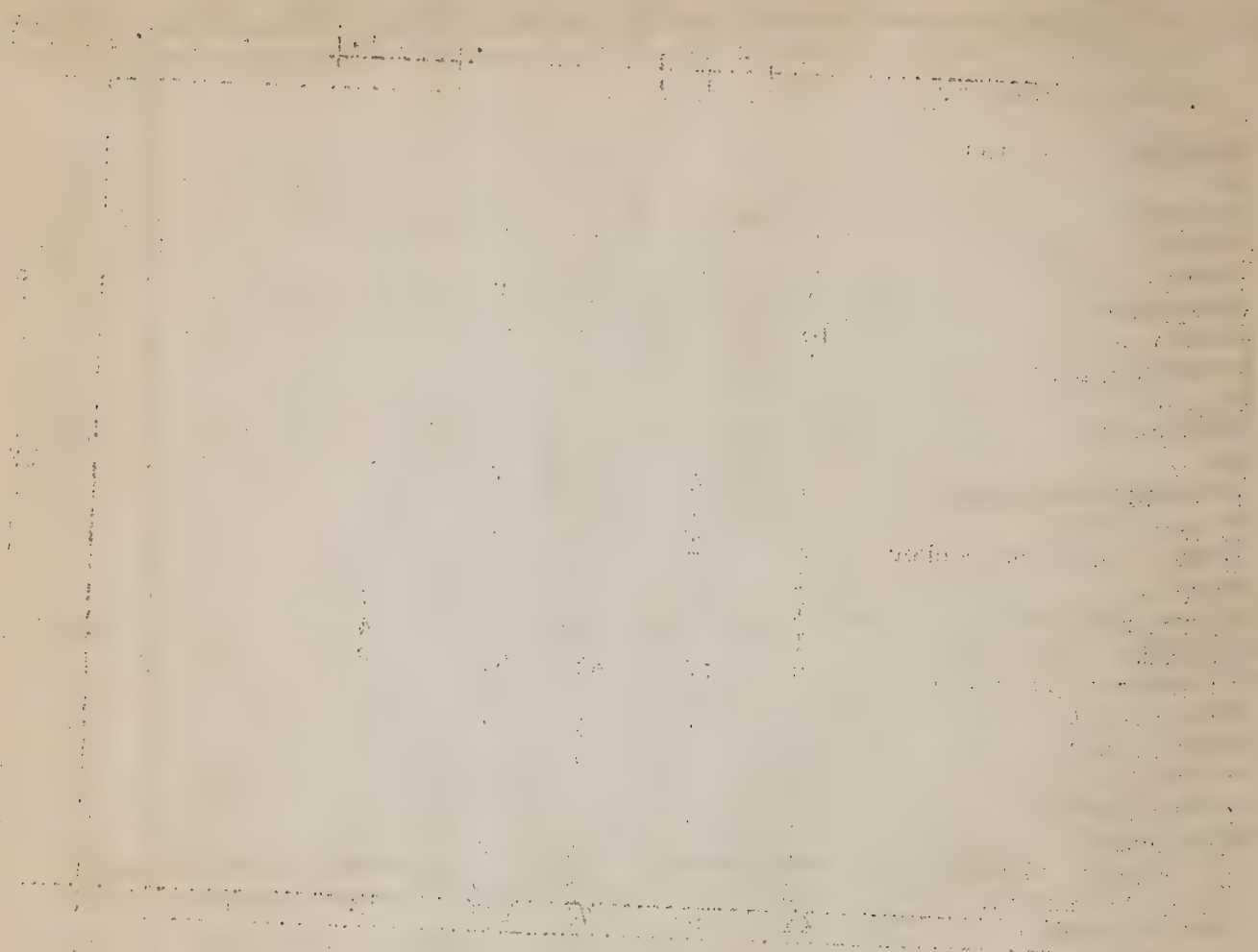


TABLE II

DEAD ANIMALS ON A 25 MILE STRETCH OF ILLINOIS HIGHWAY

January 1, 1931 to December 31, 1931

	Month	Jan.	Feb.	Apr.	May	June	July	Aug.	Sept	Oct.	Nov.	Dec.	Total
	No. of Observations	2	1	3	5	3	4	2	4	1	1	3	29
	Animal or bird												
1	Blackbird				2	1	3	1	1				8
2	Bluejay					1							1
3	Cat			2	5	1		1	3	1		1	14
4	Chicken	2		1	4		7	9	3		2	2	30
5	Dog	1										1	2
6	Dove						1						1
7	Flicker			1		2	3						6
8	Gopher				15	7	7	1	8	1			39
9	Hawk	1		1									2
10	Junco			1									1
11	Meadowlark						1						1
12	Mole						1						1
13	Opossum							1					1
14	Owl (Screech)											1	1
15	Pigeon	1											1
16	Rabbit	2		5	2		1			2	1	5	18
17	Rat	1					2						3
18	Redheaded Woodpecker					4	1						5
19	Robin				1		3		1	1			6
20	Skunk								1				1
21	Snake			2	1	2	2	3	4				14
22	Sparrow (English)	1		6	8	8	60	31	12		1		127
23	Squirrel	1											1
24	Toad				3	1		1					5
25	Turtle					1	1		2				4
26	Animals Unknown				1		1		1				3
27	Birds Unknown				5	3	4	1	3				16
	Total	10	0	19	47	31	98	49	39	5	4	10	312
	No. of Miles	50	25	75	125	75	100	50	100	25	25	75	725
	Average No. of Animals per Mile	.2	0	.25	.38	.41	.98	.98	.39	.2	.16	.13	.43

TABLE III

DEAD ANIMALS ON A 25 MILE STRETCH OF ILLINOIS HIGHWAY

January 1, 1932 to December 31, 1932

	Month	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Total
	No. of Observations	3	3	3	6	2	5	4	4	3	2	35
	Animal or bird											
1	Blackbird				1	1				1		3
2	Catbird							1				1
3	Cat	1	1	1	2	1	4	1	2	1		14
4	Chicken		1	1	3	4	5	3	4	2		23
5	Dog			1							1	2
6	Flicker						1					1
7	Frog							1				1
8	Gopher			1	15	2	10	4	6	4		42
9	Guinea Fowl			1								1
10	Junco			1								1
11	Meadowlark							2				2
12	Mouse	1							1			2
13	Owl (Screech)					1						1
14	Rabbit	2		3	6		5	2	3	3	9	33
15	Rat			1	1					1		3
16	Redheaded Woodpecker				1		2	1				4
17	Robin				3	1	3					7
18	Skunk								2			2
19	Snake				6	4		1	4			15
20	Sparrow (English)	1	1	4	27	13	68	37	17	5	2	175
21	Thrasher					1						1
22	Turtle					2	1	1				4
23	Animals Unknown			1	1		2	2		1		7
24	Birds Unknown		1	3	3	5	10	5	1	2	2	32
	Total	5	4	18	69	35	111	61	40	20	14	377
	No. of Miles	75	75	75	150	50	125	100	100	75	50	875
	Average No. of Animals per Mile	.07	.05	.24	.46	.7	.88	.61	.4	.26	.28	.43

TABLE IV--SUMMARY
DEAD ANIMALS FOUND ON A 25 MILE STRETCH OF ILLINOIS HIGHWAY
May 1, 1930 to December 31, 1932

Year	1930		1931		1932		Total
No. of Observations	20		29		35		84
Animal or bird		Ave. No. per Mile		Ave. No. per Mile		Ave. No. per Mile	
1 Blackbird	1		8		3		12
2 Bluejay			1				1
3 Catbird					1		1
4 Cat	10	.02	14	.019	14	.016	38
5 Chicken	31	.062	30	.041	23	.026	84
6 Dog			2		2		4
7 Dove			1				1
8 Flicker	5		6		1		12
9 Frog					1		1
10 Gopher	37	.074	39	.053	42	.048	118
11 Guinea Fowl					1		1
12 Hawk			2				2
13 Junco			1		1		2
14 Meadowlark	3		1		2		6
15 Mouse	1				2		3
16 Mole			1				1
17 Muskrat	1						1
18 Opossum			1				1
19 Owl (Screech)	1		1		1		3
20 Pigeon			1				1
21 Rabbit	22	.044	18	.025	33	.038	73
22 Rat	3		3		3		9
23 Redheaded Woodpecker	7		5		4		16
24 Robin	1		6		7		14
25 Skunk	2		1		2		5
26 Snake	5		14		15		34
27 Sparrow (English)	146	.292	127	.175	175	.2	448
28 Squirrel	2		1				3
29 Thrasher	4				1		5
30 Toad	1		5				6
31 Turkey	1						1
32 Turtle	3		4		4		11
33 Animals Unknown	12		3		7		22
34 Birds Unknown	18		16		32		66
Total	317		312		377		1006
No. of Miles	500		725		875		2100
Average No. of Animals per Mile		.634		.43		.43	.48

A REPORT ON TESTS OF FUNGICIDES FOR THE CONTROL OF ELM DISEASES IN NURSERIES

J. C. Carter

STATE OF ILLINOIS

Honorable Henry Horner, Governor

Department of Registration and Education

NATURAL HISTORY SURVEY DIVISION

Theodore H. Frison, Chief

Biological Notes No. 4 Urbana, March 30, 1935

Contribution from the

Section of Applied Botany and Plant Pathology

In considering this report, it should be remembered that the use of sprays and dusts as fungicides has been developed almost entirely in connection with orchards and plants from which a fruit crop is taken. With these, the problem has been chiefly the prevention of those types of infection which recur, year by year, on the leaves, blossoms, and fruit and whose effect is apparent chiefly in damage to leaves or in ruination of fruit. The value of fungicides to trees which provide ornament and shade has been inadequately tested. Formerly spraying of trees was much recommended, because it ought to do them good; but now it is the general practice of tree experts to spray only when there is definite need. The data here presented are among the first to give light on the value of spraying young growing trees for disease prevention.

L. R. Tehon

A REPORT ON TESTS OF FUNGICIDES FOR THE CONTROL OF ELM DISEASES IN NURSERIES

J. C. Carter

SINCE 1931 tests have been conducted to determine whether or not certain spray and dust materials commonly employed in the prevention of infection by fungus diseases would be effective in reducing the amount of infection occurring in growing elms under nursery conditions. For the information of nurserymen and others, the results obtained in these tests are presented and preliminary recommendations for their use are suggested.

Materials and Methods

Throughout, all tests have been made with the cooperation of the owners upon seedling American elm stock. Test plots have been set apart in the midst of blocks of trees being grown in the usual manner for the usual marketing, and the conditions under which all tests have been made are those which normally obtain in the commercial production of trees. Ten plots, utilizing for test and check purposes nearly 14,000 trees, have been used in these tests.

In general the plan has been to arrange the plots so as to compare the use of a fungicide with its non-use, and in nearly every case to test also the value of pruning out diseased material, alone and in combination with a fungicide.

The fungicides that have been employed are representative of those that have been found effective in orchards. The fungicidal chemicals are only two, copper and sulfur, copper being applied in the form of Bordeaux mixture and sulfur in two forms, as a dry dust applied directly to the trees and as a spray in which sulfur dust (called wettable sulfur) is suspended in water by mixing. The exact materials used in these tests are as follows:

1.--Bordeaux mixture. We have used a dry preparation of copper sulfate and lime prepared by the Corona chemical division of the Pittsburgh plate glass company. It needs only to be mixed, as received, with varying amounts of water to furnish Bordeaux mixtures having equal weights of its ingredients, "4-4-50," "5-5-50," or similar formulae depending only upon the amount of water used.

2.--Koloform. A sulfur dust of the wettable type manufactured by the Niagara sprayer and chemical company for use as a sulfur spray. Agitation of the dry dust in water mixes it with the water so that it can be applied as a spray.

3.--Dry Wettable Flotation Sulfur. This sulfur dust, manufactured by the Koppers products company, is similar to (2) above, but is produced in the manufacture of illuminating gas and is made up of extremely fine sulfur particles.

4.--Kolodust. This is a sulfur dust manufactured by the Niagara sprayer and chemical company. This fungicide is similar to Koloform but is applied as a dust.

5.--Flotation Sulfur Dust. This is a sulfur dust manufactured by the Koppers products company. It is composed of extremely fine particles and is used as a dust.

Applications of Bordeaux and wettable sulfurs have been made with sprayers owned by the nurserymen on whose grounds the trees have been located. The apparatus has varied from a 50 gallon hand operated outfit to a 100 gallon power machine. In different plots the quality of application has necessarily varied somewhat, though every effort has been made to secure the best possible spray coverage. Applications of sulfur dusts were made with a hand duster of standard make capable of throwing dust in a good cloud to a height of 10-12 feet. In dusting, choice of the time of day was made so as to take advantage of dew as a dust holder.

First applications have been made yearly in May or early June, and these have been followed at approximately 3 week intervals by other applications, the last being made in the last half of August. The test plots have, therefore, received treatment 4 to 6 times during each growing season. Emphasis has been laid on the summer treatment, since the so-called "wilt" generally begins to appear in July. Dormant applications have not been tested, since the possible effectiveness of fungicides was unknown.

Results

During and at the end of each season observations on the effectiveness of the various treatments have been made with care. These observations have related primarily, of course, to the usefulness of each fungicide in keeping down the general run of elm diseases included in the term "elm wilt," as used by nurserymen. But other questions have been kept in mind also, such as whether fungicides affect the prevalence of leaf diseases and whether their use is generally beneficial or deleterious to trees. These points are reported on below.

1.--Control of "wilt" diseases. It was realized, when these tests were begun, that curing infections already present would be impossible, unless pruning should prove effective. The measure of the usefulness of each treatment would lie in its ability to prevent the occurrence of new infections. Presumably, the relative values of the different fungicides would be determined also by their relative degrees of success. Whether complete cure and prevention could be attained would be determined from combined fungicide and pruning treatments. Table 1 on the following page shows in brief summary the results now at hand.

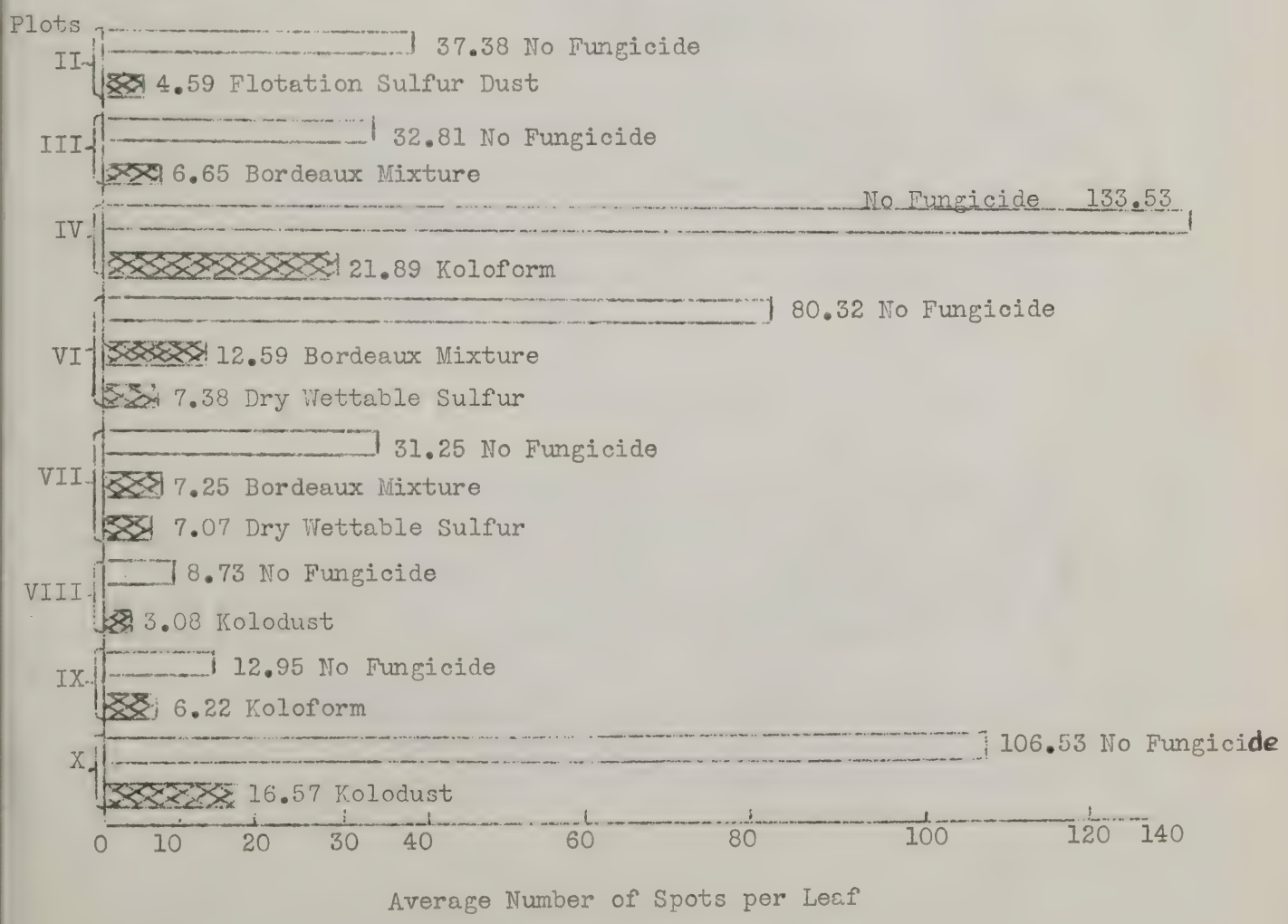
Table 1.--Results of experiments in preventing the occurrence of new infections by the "wilt" disease fungi, 1931-1935.

Plot	Treatment	Per cent of increase in "wilt" cases over those originally present	Plot	Treatment	Per cent of increase in "wilt" cases over those originally present
	Flotation sulfur dust	513		Bordeaux	300
II	Sulfur and pruning	424	III	Bordeaux and pruning	322
	Pruning	413		Pruning	100
	Check	1231		Check	414
	Kolodust	372		Bordeaux	48
I	Check	450	VI	Check	28
	Kolodust	284		Bordeaux	124
VIII	Kolodust and pruning	375	V	Bordeaux and pruning	147
	Pruning	446		Pruning	575
	Check	461		Check	176
	Kolodust	100		Bordeaux	1700
X	Kolodust and pruning	128	VII	Check	909
	Pruning	53		Koloform	119
	Check	50	IV	Check	132
VI	Flotation sulfur spray	49	IX	Koloform	223
	Check	28		Check	145
VII	Flotation sulfur spray	1300	IX	Koloform	8400
	Check	909		Check	5550

In general, the use of the sulfur dusts has been accompanied by fewer new wilt infections than has the use of sprays. Flotation sulfur dust has been somewhat more effective than Kolodust, perhaps because it is composed of finer particles and gives a more even coverage of the leaves. The data in table 1 indicate that Bordeaux is somewhat more effective in reducing the number of cases of wilt infection than are either of the two sulfur sprays used. Neither sulfur spray proved materially effective in preventing the occurrence of new cases of wilt infection.

2.--Control of leaf diseases. Leaf diseases, particularly those that result in spotting, occur in varying amounts from one year to another, their abundance and severity depending largely on the prevalence of weather favorable or unfavorable to them. When present in severe amounts, they bring about heavy defoliation at a time when the leaves should be building up a reserve supply of food materials and thus undoubtedly seriously influence

Diagram I. The effectiveness of certain fungicides in reducing the amount of leaf-spotting on elms by parasitic fungi in 1932, a season when this type of injury was exceptionally prevalent.



the growth of trees. They are generally more prevalent and abundant under nursery conditions, because of the short intervals between trees, the shade present, and the more moist atmosphere.

The effectiveness of the fungicides used in our tests on the general prevention of leaf spottings is shown in the preceding diagram, which is based on data very carefully taken in 1932, a season of exceptionally severe leaf spotting.

3.--General effect on growth of trees. In order to determine whether, aside from the control of disease, the use of treatments might have an effect on the growth of trees, the diameter of all trees, both under treatment and in check rows, was taken near the end of the 1934 growing season. A reasonable sale price was established for the several diameters and a money value figured for all plots and treatments. The effect of the treatments can be expressed tentatively in terms of dollars, merely to show what may be realized from the use of treatments in the hands of a nurseryman able to dispose of his stock at a fair price. The estimated money value for each treatment is listed in table 2.

Recommendations

The results thus far obtained in our tests indicate that sulfur dusts can be recommended as practical for summer use, for the purpose of preventing new infections by the so-called elm "wilt" diseases. Sprays, especially the wettable sulfurs, do not, however, appear to be as practical for the same purpose, although good control may sometimes be obtained with them. Where the problem is the prevention of leaf spotting, any of the materials tested will give good results, but the use of dusts may offer some economies in equipment and time.

Instructions

1.--Application of dusts: Sulfur dusts may be applied with a small hand power duster until the trees reach a height of 8-10 feet. Thereafter, a larger apparatus is necessary. Dust should be applied when the foliage is slightly moist, as in the early morning when dew is present or just after a light rain. Dusting when no moisture is present gives poor adherence of the dust and may, moreover, result in burning of the leaves.

2.--Bordeaux mixture must be sprayed onto the trees. Any sprayer that develops sufficient power to force the mixture in a fine mist to the tops of the trees and give good coverage of both leaves and bark will be satisfactory. Both "3-3-50" and "4-4-50" mixtures have been used without injury to the leaves.

Table 2.--Comparative estimate of money value of treated and untreated elm stock.

ge of trees at start	Original number of trees	Duration of experiment, years	Treatment	Estimate of value in 1934	Amount gained or lost by treatment	Calculated gain or loss per 1000 trees
	225		Sulfur dust	$185.14	$33.03 gain	$146.80 gain
12th	225		" and pruning	159.82	7.71 gain	34.27 gain
eason	225	3*	Pruning	138.17	13.94 loss	61.95 loss
	225		Check	152.11		
10th	100		Kolodust	108.67	42.45 gain	424.50 gain
eason	100	3**	Check	66.22		
	400		Kolodust	76.95	.20 loss	.50 loss
3rd	400		" and pruning	94.52	17.37 gain	43.42 gain
eason	400	3	Pruning	87.37	10.22 gain	25.55 gain
	400		Check	77.15		
	200		Kolodust	132.40	.93 gain	4.65 gain
3rd	200		" and pruning	118.47	13.00 loss	65.00 loss
eason	200	3	Pruning	108.82	22.65 loss	113.25 loss
	200		Check	131.47		
	300		Bordeaux	132.42	22.05 loss	73.50 loss
4th	300		" and pruning	118.07	36.40 loss	121.33 loss
eason	300	4	Pruning	129.37	25.10 loss	83.67 loss
	300		Check	154.47		
	144		Bordeaux	88.97	30.82 loss	214.03 loss
7th	146		" and pruning	88.97	30.82 loss	211.10 loss
eason	140	4***	Pruning	82.82	36.97 loss	264.07 loss
	146		Check	119.79		
	237		Bordeaux	142.30	22.13 gain	97.57 gain
2nd	237		" and diseased trees removed	138.85	19.68 gain	83.03 gain
eason	237	3	Diseased trees removed	173.40	54.23 gain	228.81 gain
	237		Check	119.17		
9th	576	3	Bordeaux	577.60	66.82 gain	116.01 gain
eason	576		Check	510.78		
	237		Sulfur spray	145.80	26.63 gain	112.36 gain
2nd	237		" and diseased	161.40	42.24 gain	178.18 gain
eason		3	trees removed			
	237		Check	119.17		
9th	576		Sulfur spray	470.90	39.88 loss	69.23 loss
eason	576	3	Check	510.78		
3rd	1000		Koloform	427.75	46.55 gain	46.55 gain
eason	1000	3	Check	381.20		
3rd	347		Koloform	143.82	15.45 gain	44.52 gain
eason	347	3	Check	128.37		

*Treated for 2 seasons, data taken at end of 3rd season. **Treated for 1 season, data taken at end of 3rd season. ***Treated for 3 seasons, data taken at end of 4th season.

3.--Dry wettable sulfurs are received in the form of dust. They are readily mixed with water, the proportions required being indicated either on the container in which they are received or in instructions furnished by the manufacturers. We have used 15 pounds of Koloform to 100 gallons of water and 7 pounds of dry wettable flotation sulfur to 100 gallons of water.

4.--Times for applications. For the control of the "wilt" diseases, not less than 4 applications should be made each summer. Preferably, the first should be made as soon as the first foliage is out and solidly formed. Subsequent applications may be made at even intervals, spaced according to the number of applications planned but also with due respect to heavy rains, which tend to wash off both sprays and dusts.

When control of leaf spotting is especially desired, applications of either sprays or dusts should be made with reference to new leaf growth, care being taken that new leaves be not left unprotected very long. Applications at 3 week intervals are recommended.

SUGGESTIONS FOR MANAGEMENT OF UPLAND GAME IN ILLINOIS

R. E. YEATTER

STATE OF ILLINOIS
Honorable Henry Horner, Governor
Department of Registration and Education
NATURAL HISTORY SURVEY DIVISION
Theodore H. Frison, Chief

Biological Notes No. 5 Urbana, May 15, 1935

Contribution from the Section of Game Research and Management
Publication 261

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SUGGESTIONS FOR MANAGEMENT OF UPLAND GAME IN ILLINOIS

R. E. Yeatter

To produce a permanent population of upland game it is obvious that farmlands must possess (1) adequate cover for protection at all times of the year, (2) places for nesting and rearing young, (3) a year-round food supply. The great majority of Illinois farms are lacking in one or more of these requirements and therefore possess a minimum of game and other wildlife.

Food and Cover

Proper distribution of food and cover is necessary. For the less mobile species the winter food supply on the farm may be too far distant from cover to be available. Even pheasants or other game that ranges widely suffer undue losses if they have to go too far for food in winter.

Farmers and other landowners who desire to increase the amount of useful wildlife on their lands may usually do so by making available weed seed or grain food during the critical winter and early spring periods, and by plantings of thorny shrubs, or by allowing woodlots, corners, roadsides, ditch banks and fence rows or eroded areas to produce grass and brush cover.

Cover.—Dense brushy cover is important to farm game as a means of escaping enemies. Furthermore, it promotes a feeling of security which keeps game from wandering away.

Although this type of cover is most important for quails, it is also used by other kinds of game, including the field-inhabiting Hungarian partridge. Very small and isolated cover areas may not always be used but dense, tangled cover areas, not too far apart, are more important than one or two large thickets. Brushy areas that are too thin may become good cover if burnings and grazing are prevented, or where interplanted with evergreens or other shrubs. Brush piles, standing corn and grain plantings for food patches may also be provided to supplement existing cover.

The common trees and shrubs most useful for game protection and food in Illinois include black locust, willows, pines, spruces, mulberries, haws, plums, wild grapes, wild roses, wild honeysuckle, blackberries, raspberries, hazel and buckbrush. Mulberries and most of the shrubs also produce attractive summer or autumn food. Many of these can be secured locally by going to the wooded areas for them. The forestry section of the Illinois Natural History Survey will advise as to sources of reasonably priced tree planting stock.

Food.—Food patches should be located not more than one hundred yards from good cover, and for best results should be at least one-quarter to one-half acre in extent. Experiments at the University of Wisconsin indicate that food patches should contain two types of grains with respect to the ability to stand up during the winter. (1) Stiff-stemmed varieties including wheatland milo, kalo sorghum, feterita, kaffir corn and field corn or sweet corn; (2) Grains which lodge under snow but last over winter and provide food in early spring. The cane sorghums, especially Black Amber and Red Amber, are outstanding in this respect. These grains are planted from May 15 to June 15

and ordinarily should be planted in separate rows—not mixed. Plant not over 10 pounds to the acre to insure seeding. Where it is possible to devote as much as one acre to a food patch half of the area should be planted the first spring, and the other half the following spring, while allowing the first to lie fallow. This plan provides an additional supply of weed seeds and also provides excellent nesting cover.

Nesting cover.—Provision of undisturbed nesting cover is essential to successful game management. Avoid unnecessary burning of wide fence rows and roadsides at any time of the year. Fence off and plant or allow natural growth of brush and grass of all eroded areas. Leave field corners and strips of ungrazed grass along ditch banks. Grassy strips should be eight feet or more wide to minimize danger from nest-robbing enemies.

In fields the majority of game-bird nests lie within the first 25 or 30 feet from the edge. By making three or four trips on foot around hay fields ahead of the mowing machine, these nests may be located and an "island" of vegetation left around them during mowing.

Flushing bars attached to mowing machines work well under some conditions, but have not yet been tried out sufficiently in Illinois to enable us to state which type is best suited to our conditions.

Although the native species—quails, rabbits and squirrels—thrive everywhere in the state where favorable conditions are provided, pheasants and Hungarian partridges appear not

to be well adapted to latitudes of southern Illinois, probably because of unfavorable influences associated with climate.

Management Suggestions

Quails, pheasants, partridges and rabbits are the more common kinds of farm game in Illinois.

Quail.—(1) For a maximum population establish as many dense brushy tangles as possible. Ungrazed woodlots, plum and hawthorn thickets, especially where wild grapes are present, thick hedges, plantings of locusts, buckbrush and honeysuckle in gulleys are the type of cover necessary for quail. Remember that well-distributed coverts of good quality are more effective than a single large thicket. Two areas of evergreens and brambles each 50 feet long or more per 40 rods of fence line may be nearly as effective as a continuous hedge.

(2) Supplement brushy areas that are too thin with brush piles and corn shocks open at the bottom. An artificial shelter may easily be made by encircling a wigwam-shaped frame of poles with several turns of barbed wire and training around it a grapevine that is growing on the fence or ground nearby.

(3) Insure a winter food area of ungrazed standing corn or a patch of small grain and weeds within 75 yards of each good brushy area.

(4) For nesting cover, protect wide roadsides and other grassy places from burning or pasturing in autumn or spring.

Allow corners, ditchbanks, old orchards and gulleys or other waste areas to grow up to grass and vines.

Pheasants.—(1) Ungrazed standing corn, marshlands or weedy fields are the most important pheasant cover in Illinois. Cover of this type is most effective when brush or hedge cover is also present. Hedges, dense willow patches along streams, and brushy gulleys are important for travel lanes and for headquarters for the male birds during the nesting season.

(2) Dense herbaceous growth, grass or food patches along ditches are attractive hiding places.

(3) To insure adequate winter food, leave several rows of ungrazed standing corn, preferably weedy, with part of the ears unhusked until spring, or plant food patches along ditches, marshlands or close to brushy cover.

(4) The majority of nests are made in hay or grass fields in most sections of Illinois. Look for nests in the outside 25 or 30 feet of hay fields.

(5) Prevent dogs and cats from ranging the fields during the nesting season.

Hungarian partridges.—(1) Brushy cover is not necessary for Hungarian partridges if ungrazed standing corn fields are present during the winter. Several rows should be protected from grazing to provide winter cover and food for each covey of birds.

(2) In small grain sections stubble should be cut high to provide cover for young in summer. Strips of weedy stubble

should be left unplowed along hedges until spring.

(3) For winter food leave a few rows of unhusked standing corn, or plant small grain or sweet corn food patches near hedges or corn fields.

(4) The tendency to nest in hay fields or in exposed locations where nesting cover is inadequate calls for special attention to nesting cover. Protect wide ditch banks and roadsides from burning and do not mow weedy areas or roadsides until after July 15. Pastures that are not grazed too hard in May and June may provide safe nesting places. Look for nests in the outside 30 feet of the alfalfa fields. Populations of Hungarian partridges can be built up by attention to winter foods and nesting grounds.

Rabbits.—(1) Rabbits thrive best in regions where a variety of cover is present. Hedges are useful for hiding places and for travel lanes. Brush piles, thickets of plum, raspberry and buckbrush are important refuge covers. Cord wood piled on poles, old farm machinery and rolls of old wire are used extensively. Old tiles and hollow limbs along hedges provide considerable protection.

(2) Food patches, clover fields, standing corn, sumac, berry vines and piles of pruned apple limbs are important sources of food. Corn fields are important winter feeding and ranging grounds if adjacent to woodlots or thickets.

As for other possible game species, undisturbed grassy areas are most important as nesting places.

THE RELATION OF EAR ROT PREVALENCE IN ILLINOIS CORN FIELDS TO EAR COVERAGE BY HUSKS

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Department of Registration and Education
NATURAL HISTORY SURVEY DIVISION
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THE RELATION OF EAR ROT PREVALENCE IN ILLINOIS CORN FIELDS TO EAR COVERAGE BY HUSKS

G. H. Boewe

In the fall of 1930, while examining Illinois corn fields to determine the prevalence of disease, casual observation seemed to indicate to the writer that ears poorly covered by husks were much more readily infected by rot-producing fungi than those that were well covered. In the main, ear rots are caused by fungi, the spores of which are carried directly to the ears by various agencies, chiefly the wind, although some infection results from the fungi which grow from the stalk into the ear. An ear completely enclosed by its husks during the entire course of its development would appear to have been protected from external infection, while an ear not completely covered would appear to have been exposed to external infection. Yet ears poorly covered often escape infection and many well covered ears become infected.

It seemed worthwhile, therefore, to determine whether any relation does exist between husk coverage of the corn ear and the prevalence of ear rots in Illinois corn fields. Data bearing on this point have been accumulated by direct field examination during the 5-year period, 1931-1935, and a total of 57,395 ears have been examined in 297 fields. Corn fields have been examined each year in all parts of the state, except in 1931, when only fields in the central part were examined. The number of fields and the number of ears examined have varied from year to year, as shown in Table 1, but in general both the number of fields and the number of ears examined tended to be greater in each succeeding year. Records for the entire period show

that fields were examined in 69 of the 102 counties in the State.

DEFINITION OF TERMS

Throughout this discussion "covered" and "well covered" are to be understood as signifying that ears so classed were covered completely by husks, including the tips, and that the husks remained tightly closed until near harvesting. For the first 2 years, 1931 and 1932, these terms apply rigidly to ears observed to be completely and tightly covered by husks when the fields were examined. "Open," "not covered," and "not well covered" signify that ears so classed were not completely covered, but no distinctions have been made relative to the degree of partial coverage and none is implied by the various terms used.

Since the data are concerned with visually discernible ear rots, "ears with visible infection" and "ears without visible infection" constitute the 2 classes into which corn ears were assorted upon examination. Ears were considered to be rot-free if, at the time of examination, no visible mold or fungus sporulation appeared on or between the kernels or on the cob. Naturally, no account could be taken of the hidden infections which require the use of a germinator for determination.

RELATIVE ABUNDANCE OF COVERED AND OPEN EARS

Since most of the corn seed used in Illinois is produced by open pollination and is genetically heterozygous, it might be expected that covered and open ears would be found to occur in approximately equal numbers. However, an increasing number of farmers are practicing field seed selection, and, since this involves the choice of covered in preference to open ears, the expected ratio may not be secured. It is commonly believed, also, that weather and other conditions tend to influence ear length and size, thereby determining whether the ears will be covered or not by the supposedly uniform husks.

In Illinois corn fields, as shown in Table 1, below, the number of open ears exceeds considerably the number of closed ears, in spite of the practice of selection and of any expected equality based on the genetic constitution of the crop. Over a

Table 1.-- Relative abundance of covered and open ears in Illinois corn fields, 1931-1935.

Year	Fields exam.	Ears exam.	Number of ears		Percent of ears	
			Open	Covered	Open	Covered
1931	26	7,800	5,314	2,486	68.1	31.9
1932	52	7,605	5,341	2,264	70.2	29.8
1933	51	9,300	5,300	4,000	57.0	43.0
1934	71	13,660	7,693	5,967	56.3	43.7
1935	78	15,880	8,424	7,456	53.0	47.0
Total	278	54,245				
Average					60.9	39.1

period of years, the average ratio of open to closed ears is almost exactly 3 to 2, and, although the ratio varies somewhat from year to year, the number of open ears exceeds the number of closed ears every year.

In a given year, considerable variation occurs in the relative number of open and closed ears in different fields, even in the same county. In Hancock County, for example, 2 fields examined in 1932 gave a ratio of open to covered ears of 4 to 1 and 2 to 3, and in Jasper County 2 fields gave ratios of 1 to 3 and 1 to 2. In 1934 and 1935, there was a larger average proportion of covered than of open ears in 5 fields in Piatt County, the ratio being 5 covered to 3 open ears, and in Edwards County in the same 2 years a ratio of 1.25 covered to 1 open was obtained.

Whenever the variety of corn in a field could be recognized, it was noted as a part of the data, and such records are combined in Table 2. Although the number of fields examined of each variety is small, a somewhat greater prevalence of covered ears is indicated for the Bloody Butcher, Calico, and Democrat varieties, while open ears predominate in the Krugg variety.

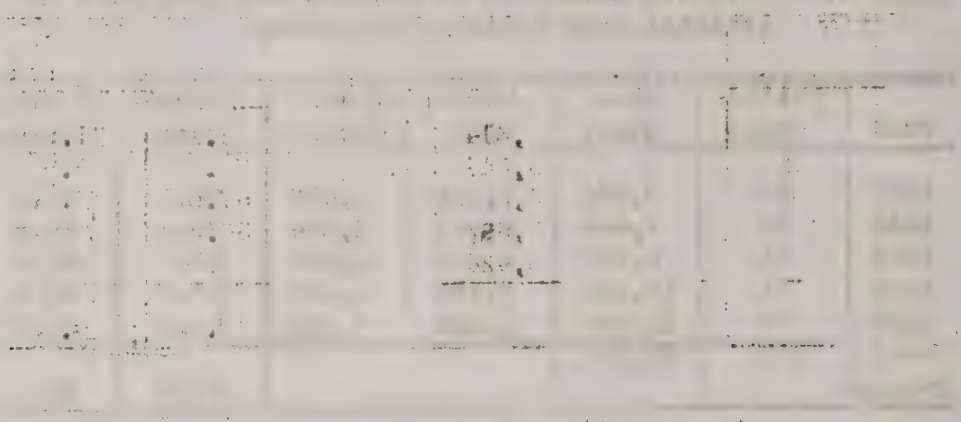


Table 2.-- Prevalence of open and covered ears in some corn varieties.

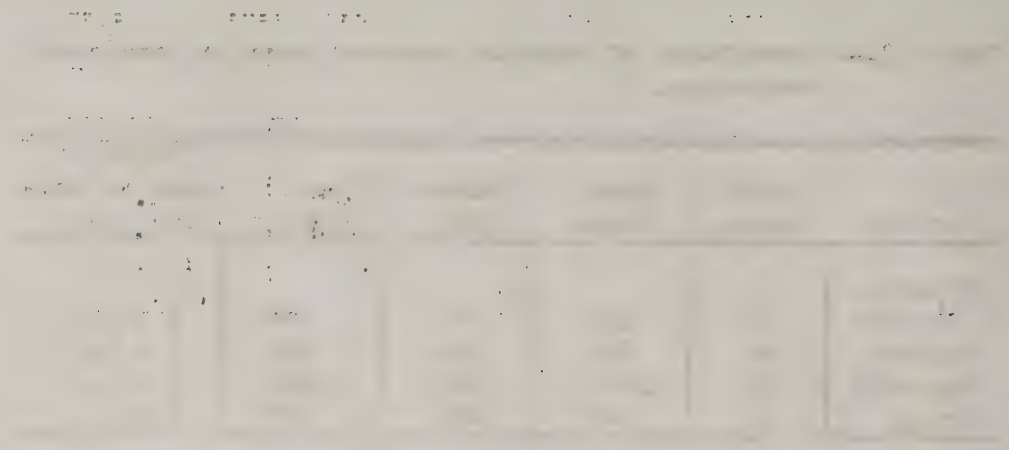
Variety	Fields exam.	Ears exam.	Number of ears		Ratio of open to covered ears
			Open	Covered	
Bloody Butcher	2	200	64	136	1 : 2.1
Calico	4	700	322	378	1 : 1.2
Democrat	12	2,000	764	1,236	1 : 1.6
Krugg	2	502	325	177	1.8 : 1

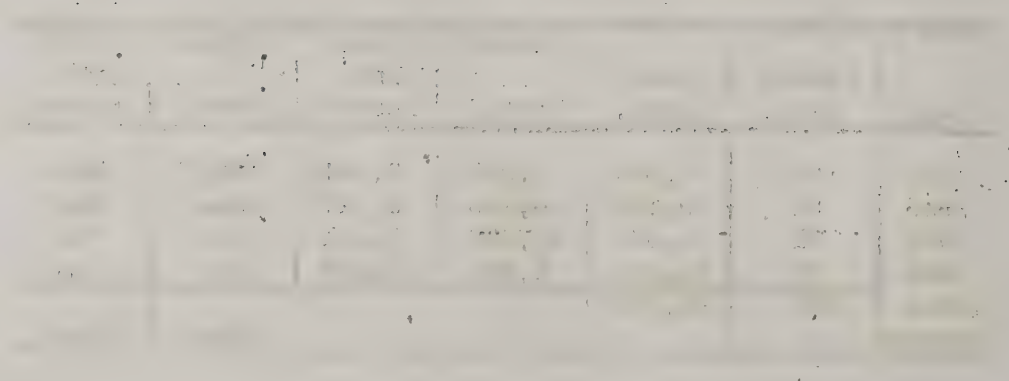
FIELD PREVALENCE OF CORN EAR ROT

The presence of ear rot was determined in the field by pulling back the husks of each ear and examining it for the presence of fungus growth or sporulation, without removing the ear from the stalk. Ears that showed superficial characters of disease but no visible mold growth, as in Basisporium and some Diplodia infections, were broken to determine whether any mycelium, spores, or fungus fruiting bodies were present and were counted as rot-infected when these were found. Data were taken on this basis, which is designed to show the total field prevalence of ear rot regardless of particular causes, only during the 4 years, 1932-1935. A summary of them is presented above in Table 3.

Table 3.-- Prevalence of ear rot in Illinois corn fields, 1932-1935.

Year	Fields exam.	Ears exam.	Number of ears		Percent of ears	
			Rotted	Not rotted	Rotted	Not rotted
1932	48	7,005	3,911	3,094	55.8	44.2
1933	51	9,300	4,183	5,117	45.0	55.0
1934	71	13,660	12,359	1,301	90.5	9.5
1935	78	15,880	4,462	11,418	28.1	71.9
Total	248	45,845				
Average					54.8	45.2





Ear rot varied in prevalence from year to year, within wide limits, being least abundant in 1935, when 28.1 percent of the ears examined were infected, and most abundant in 1934, when 90.5 percent were infected. While various factors may have been concerned in these annual variations, as for example in 1934 when ear rot was undoubtedly greatly favored by prior damage done by corn ear worms, the significance of the ear rot problem in corn production is emphasized by the fact that of over 45,800 ears examined over a period of 4 years an average of almost 55 percent were visibly infected with one or another kind of rot.

RELATION OF EAR ROT PREVALENCE TO HUSK COVERAGE

Data on the relation of ear rot, without reference to particular causes, and husk coverage have been taken over a period of 3 years, 1933-1935, and are summarized in Tables 4 and 5. Among those ears not completely covered by husks ear rot prevailed, as shown in Table 4, to a high degree in 1933 and to an especially high degree in 1934, when the percentage of rot-infected ears exceeded the uninfected ears by nearly 85 percent; but in 1935 the rotted ears, while still constituting nearly a

Table 4.-- Prevalence of ear rot in corn ears not completely covered by husks, 1933-1935.

Year	Open ears examined	Number of ears		Percent of ears	
		Rotted	Not rotted	Rotted	Not rotted
1933	5,300	2,801	2,499	52.9	47.1
1934	7,693	7,101	592	92.3	7.7
1935	8,424	2,686	5,738	31.9	68.1
Average				59.0	41.0

third of the entire number, were less abundant than sound ears. In spite of these fluctuations, the average percentages for the 3 recorded years indicate a strong tendency for open ears to become infected more frequently than covered ears.

Among those ears completely covered by husks, ear rot prevailed to a high degree also, as indicated in Table 5, but the percentage of rotted ears was less than

the percentage of clean ears in both 1933 and 1935, while in 1934 the proportion of rotted ears greatly exceeded the proportion of clean ears. The average percentages

Table 5.-- Prevalence of ear rot in corn ears completely covered by husks, 1933-1935.

Year	Closed ears examined	Number of ears Rotted	Number of ears Not rotted	Percent of ears Rotted	Percent of ears Not rotted
1933	4,000	1,382	2,618	34.6	65.4
1934	5,967	5,258	709	88.1	11.9
1935	7,456	1,776	5,680	23.8	76.2
Average				48.8	51.2

for the 3 years indicate that, among covered ears, there is a distinct tendency for clean ears to predominate.

Of more significance, however, is the direct comparison given in Figure 1 of the percentages recorded in Tables 4 and 5. In each of the 3 years, regardless of

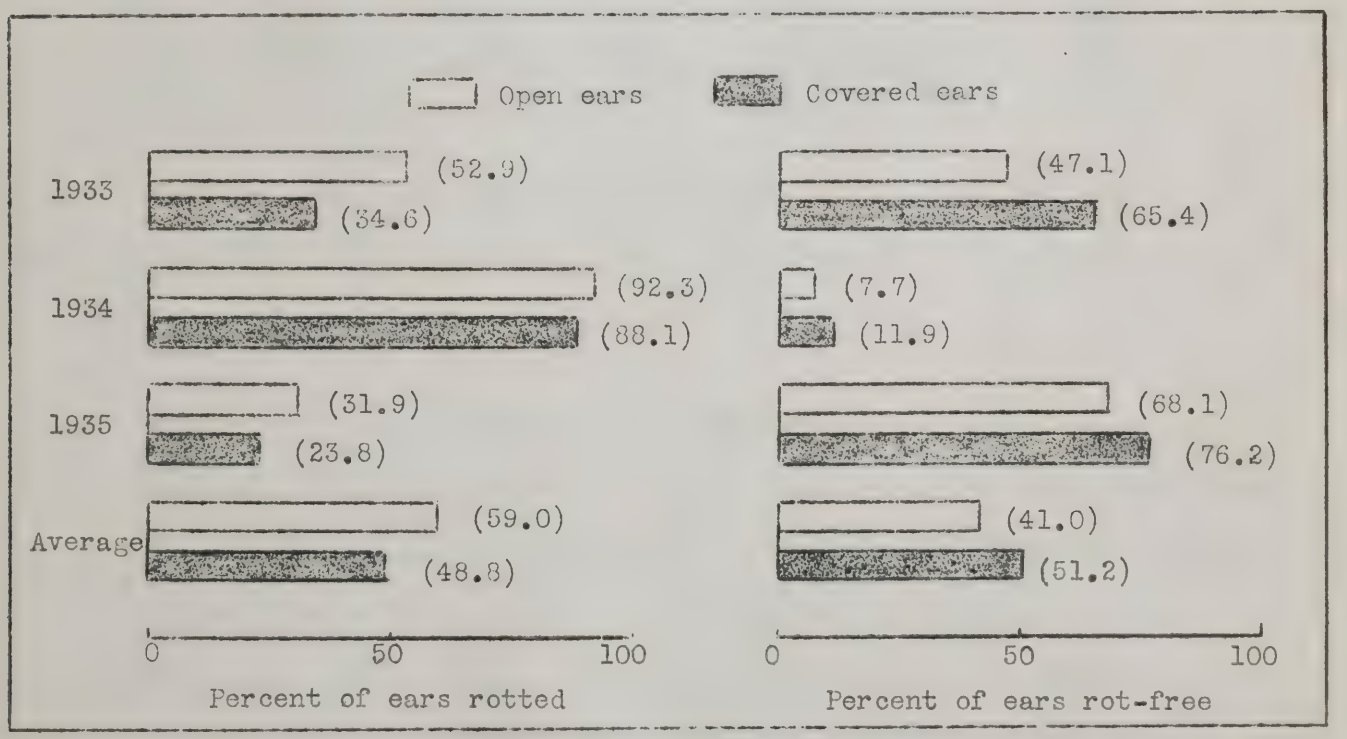
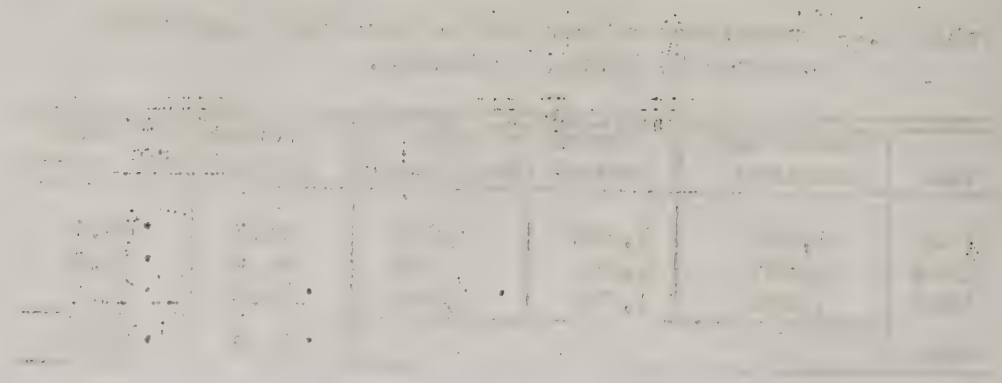
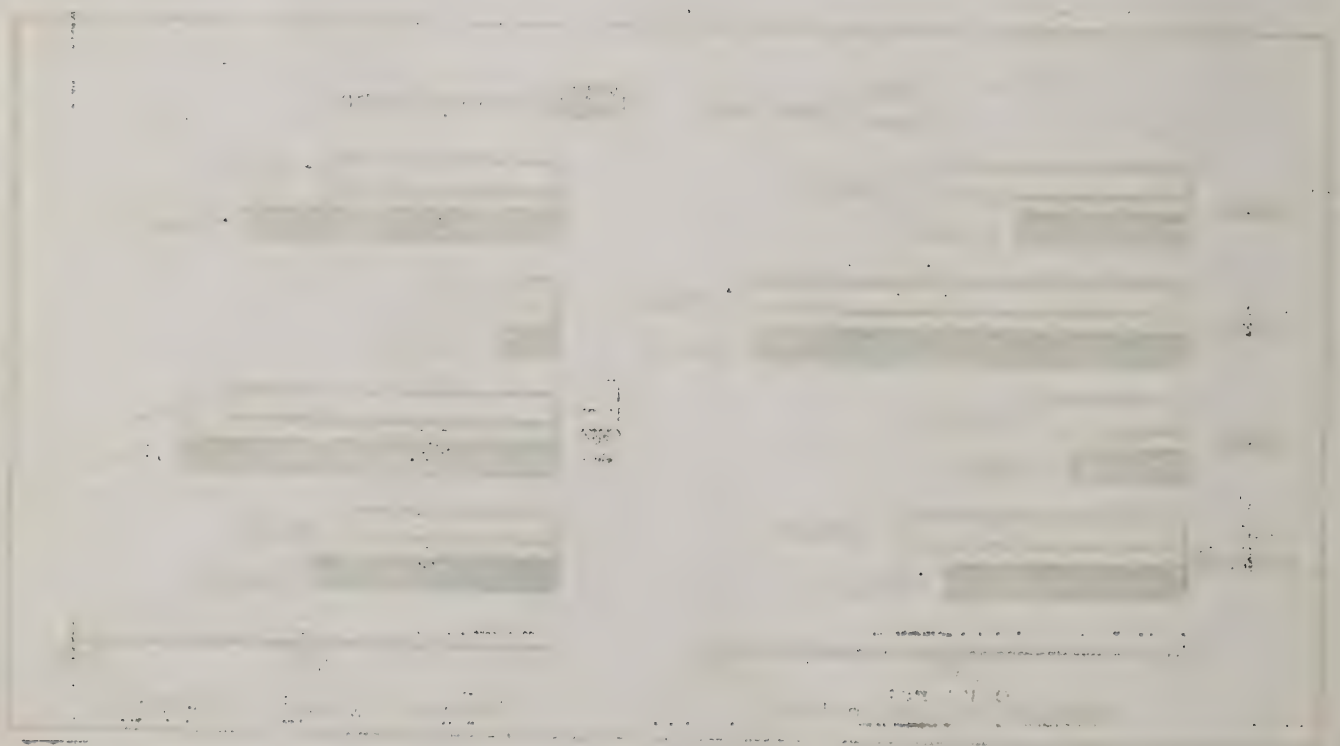


Fig. 1.-- Prevalence and absence of ear rot in open and covered corn ears, 1933-35.





the annual variation in prevalence, open ears were infected to a significantly greater extent than covered ears and, conversely, covered ears were free of rot infection to a significantly greater extent than open ears. Averages for the 3 years show a difference of 10.2 percent between open and covered ears, the open ears exceeding the covered ears to that extent in number of rotted ears, and the covered ears exceeding the open ears to the same extent in number of sound ears.

In the analysis presented in Table 6, in which the diseased ears found annually are assorted into open and closed groups and the number in each group is expressed as a percentage of the total, the difference between the percentages of open

Table 6.-- Prevalence of husk coverage types among rotted corn ears, 1933-1935.

Year	Rotted ears examined	Number of ears		Percent of ears		Excess of open, in percent
		Open	Covered	Open	Covered	
1933	4,183	2,801	1,382	67.0	33.0	34.0
1934	12,359	7,101	5,258	57.5	42.5	15.0
1935	4,462	2,686	1,776	60.2	39.8	20.4
Average				61.6	38.4	23.2

and closed infected ears each year shows consistently a marked preponderance of open rotted ears over covered rotted ears. This preponderance averages 23.2 percent for the 3-year period covered by the data.

FIELD PREVALENCE OF SPECIFIC EAR ROTS

The field prevalence of 8 of the more common and presumably more important corn ear diseases was determined annually during the 5 years, 1931-1935, by examining each year a large number of ears in a considerable number of fields. While the amount of data taken varied to some extent from year to year, as shown in Table 7, 297 fields were visited and 57,395 ears were examined during the period, and except

in 1931, when no work was done in the northern third, all sections of the state were represented in each year's data.

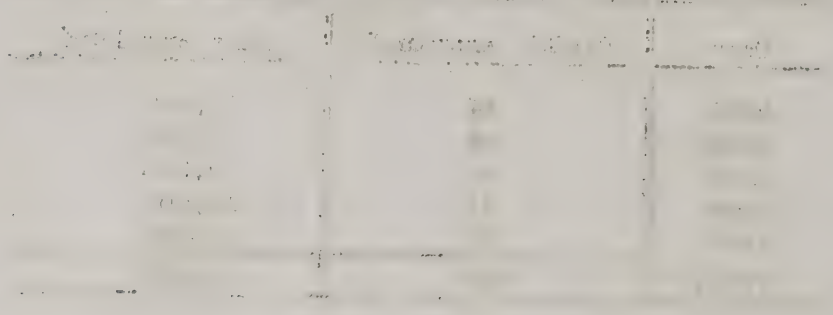
Table 7.-- Number of corn fields and ears examined for specific ear rots, 1931-1935.

Year	Fields examined	Ears examined
1931	44	10,850
1932	54	7,805
1933	50	9,200
1934	71	13,660
1935	78	15,880
Total	297	57,395

The diagnosis of specific rots was made in the field, for the most part; but, whenever the identity of a rot was questionable, a portion of the infected ear was saved for subsequent microscopic examination and identification. As a result, the actual number of ears affected with each rot, among all the ears examined, was recorded each year and indicates, on the basis of random sampling, the prevalence of each rot in each year. The recorded number of ears infected by each rot, when expressed as a percentage of the total number of ears examined each year, constitutes an index by means of which, as is done in Table 8, the relative abundance of several

Table 8.-- Field prevalence of 8 kinds of corn ear rot, 1931-1935.

Type of rot	Percent of ears rotted					
	1931	1932	1933	1934	1935	Average
Fusarium	24.0	42.4	34.6	80.6	22.0	40.7
Penicillium	11.5	6.2	4.9	4.1	2.3	5.8
Rhizopus	1.0	2.1	4.2	6.8	1.0	3.0
Smut	2.1	1.5	1.2	2.2	1.4	1.7
Diplodia	.5	1.3	2.6	1.4	.4	1.2
Gibberella	.64	.98	.32	.73	.94	.72
Basisporium	.58	.29	.36	.80	.76	.56
Aspergillus	.0	.04	.23	.83	.04	.23



rots can be shown for any year and the fluctuations of each in abundance from year to year can be ascertained readily. An average, for the 5 years covered by the data, of these yearly indexes may be considered to show with a fair degree of accuracy the average annual prevalence of each rot.

On this basis the several rots assume the order given in Table 8. Fusarium rot is shown to be the most prevalent, every year as well as in the average year, for which its index is 41 percent, while Penicillium rot stands second, with a moderate prevalence each year and an average annual prevalence of 6 percent. Between Fusarium and the remaining diseases a very large gap in both year-by-year and average prevalence is shown, the average index for Penicillium rot, most abundant of the 7, being less by 35 percent than that of Fusarium rot. The average annual indexes indicate, in fact, that over a period of years the last 7 of the 8 ear rots have an aggregate prevalence approximately one-third that of Fusarium rot.

In the annual variations there is no general agreement among the 8 rots as to trend for the entire period. There are, however, two rots which follow the same trend throughout the entire period. Rhizopus rot and Aspergillus rot both increase in prevalence in 1932 over 1931, in 1933 over 1932, and in 1934 over 1935, and both decline very markedly in 1935 from the high points of 1934. Smut and Basisporium rot also agree in trend, except for 1933, in which year the former declined from and the latter rose above the prevalence of the year before. With the other rots, similar trends may exist for short periods, but the parallelism does not hold for the entire number of years.

RELATION OF SPECIFIC EAR ROTS TO HUSK COVERAGE

When the data presented in the preceding section were taken, the corn ears affected with each rot were classified as to coverage by husks, according to the

standard described on page 2. With such data covering the entire 5-year period for 6 of the 8 rots and representing the natural fluctuation in prevalence of each rot from year to year under varied environmental conditions, the relationship of ear coverage to infection should be indicated rather accurately by the summaries presented in the following tables.

The relation of Fusarium infection to husk coverage is shown in Table 9. More diseased open than diseased closed ears were found in each of the 5 years, there

Table 9.-- Relation of Fusarium rotted ears to husk coverage, 1931-1935.

Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1931	2,622	827	76.0	24.0	52.0
1932	2,479	832	75.0	25.0	50.0
1933	2,272	916	71.3	28.7	42.6
1934	6,416	4,595	58.3	41.7	16.6
1935	2,208	1,292	63.1	36.9	26.2
Average			68.8	31.2	37.6

being 1.4 times as many infected ears in the open class as in the closed in 1934 and about 3 times as many in 1931 and 1932. Over the 5-year period, open ears averaged 68.8 percent and closed ears 31.2 percent of those infected by Fusarium, and for the entire period it appears significant that the preponderance of open infected over covered infected ears averaged 37.6 percent.

The relation of Penicillium rot to husk coverage is shown in Table 10. While there was some variation from year to year in the relative abundance of open and covered diseased ears, in each of the 5 years there were fewer diseased ears in the covered group than in the open group. The average for the 5 years shows annually

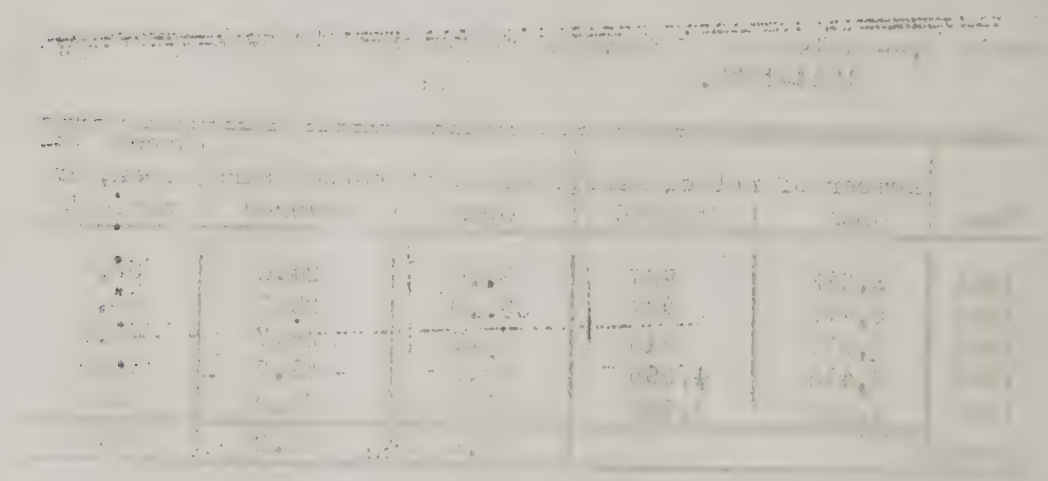


Table 10.-- Relation of Penicillium rotted ears to husk coverage, 1931-1935.

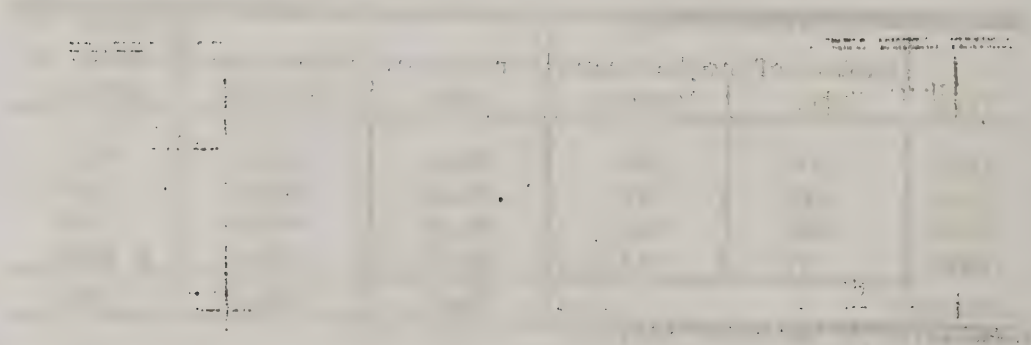
Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1931	682	413	62.3	37.7	24.6
1932	327	142	69.7	30.3	39.4
1933	286	166	63.3	36.7	26.6
1934	311	243	56.1	43.9	12.2
1935	211	153	57.8	42.2	15.6
Average			61.8	38.2	23.6

61.8 percent of the infected ears in the open class and only 38.2 percent in the closed class, or an average excess of open over covered infected ears of 23.6 percent.

Competent data on the occurrence of Rhizopus rot in relation to husk coverage were not taken in 1931, but this relationship, as shown by the data taken in the 4 following years, is indicated by the summary given in Table 11. While there is in this, as in the ear rot previously discussed, an apparent tendency for a greater prevalence of infection, averaging 9.2 percent annually for the data given, to occur on open ears, the occurrence of a much greater quantity of infection in closed ears in 1935 suggests the existence of other factors predisposing to infection that may,

Table 11.-- Relation of Rhizopus ear rot to husk coverage, 1931-1935.

Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1932	105	59	64.0	36.0	28.0
1933	215	167	56.3	43.7	12.6
1934	509	420	54.8	45.2	9.6
1935	67	87	43.5	56.5	- 13.0
Average			54.6	45.4	9.2



in some years at least, overcome the purely mechanical effect of perfect husk coverage.

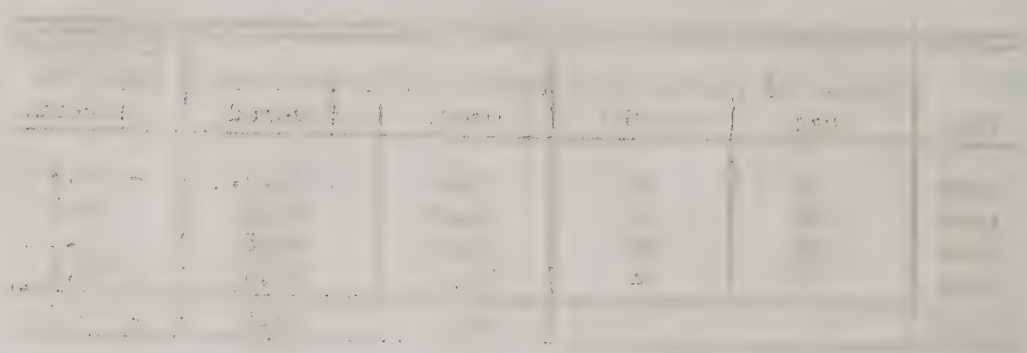
Since no Aspergillus infection was found in 1931, data on its relationship to husk coverage are available only for the 4 years beginning with 1932. According to the summary shown in Table 12, no constant correlation appears to exist. While an

Table 12.-- Relation of Aspergillus rot to husk coverage, 1932-1935.

Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1932	1	2	33.3	66.7	- 33.4
1933	13	8	61.9	38.1	23.8
1934	61	53	53.5	46.5	7.0
1935	2	4	33.3	66.7	- 33.4
Average			45.5	54.5	- 9.0

average annual excess of 9.0 percent of infection is shown in covered ears, the 2 years of highest prevalence oppose the conclusion that open ears are less readily infected by showing a decided preponderance of open infected over closed infected ears. The data presented are both inconsistent and inconclusive with respect to husk coverage but suggest the operation of other, more important factors.

In determining the relationship of smut infection to ear coverage, the exact standard of differentiation adhered to in taking data for other diseases was found to be usable with difficulty, and the summary given in Table 13 should be considered in that light. Since any considerable number of infected kernels on an ear invariably results in the bursting open of the husks, because of the size of the smut galls, it is undoubtedly a fact that the very large differences in number and percentage of open infected and closed infected ears in reality grossly exaggerates



any tendency towards more frequent infection of ears exposed through incomplete husk coverage. But it can hardly be doubted that such a tendency does exist when, with reasonable care practiced in the classification of ears, an excess of open infected

Table 13.-- Relation of smut infected ears to husk coverage, 1931-1935.

Year	Number of infected ears		Percent of infected ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1931	147	22	87.0	13.0	74.0
1932	60	4	93.7	6.3	87.4
1933	103	10	91.1	8.9	82.2
1934	262	43	85.9	14.1	71.8
1935	210	16	92.9	7.1	85.8
Average			90.1	9.9	80.2

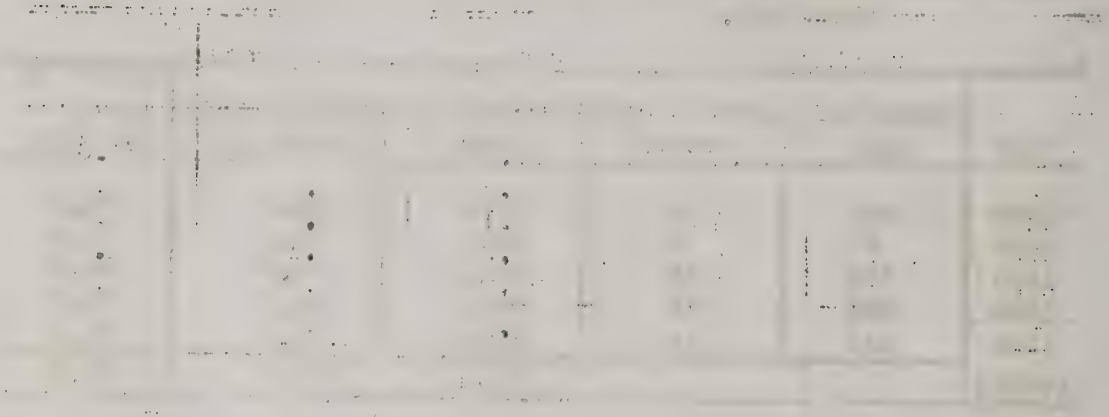
over closed infected ears is found, ranging in different years from 71.8 to 87.4 percent and averaging annually 80.2 percent.

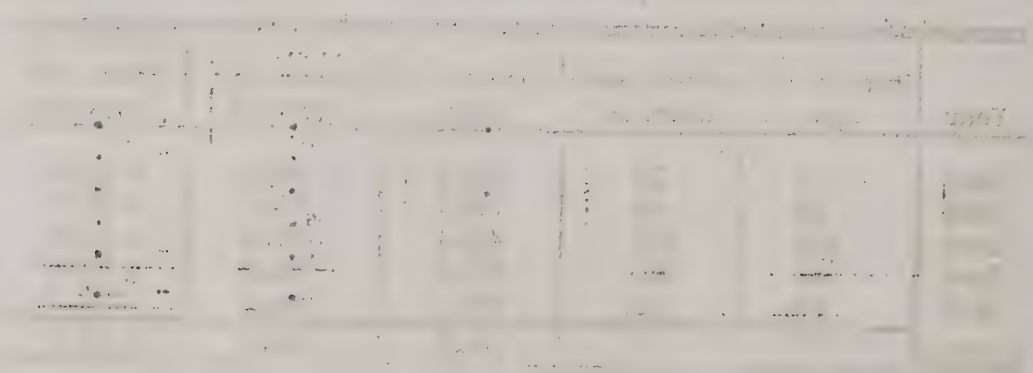
The assortment with respect to husk coverage of the Diplodia rotted ears found each year is shown in Table 14. In every year a greater number fell in the

Table 14.-- Relation of Diplodia rot to husk coverage, 1931-1935.

Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1931	13	16	44.8	55.2	- 10.4
1932	26	54	32.5	67.5	- 35.0
1933	103	133	43.6	56.4	- 12.8
1934	67	121	35.6	64.4	- 28.8
1935	23	38	37.7	62.3	- 24.6
Average			38.8	61.2	- 22.4

covered than in the open class, and for the 5 years concerned the open infected ears averaged 22.4 percent fewer annually than the covered infected ears. This negative





correlation between exposed ears and abundance of infection argues strongly against the protective effect of complete husk coverage and emphasizes to an equal degree the important role, in this disease, of ear invasion through the shank and silks.

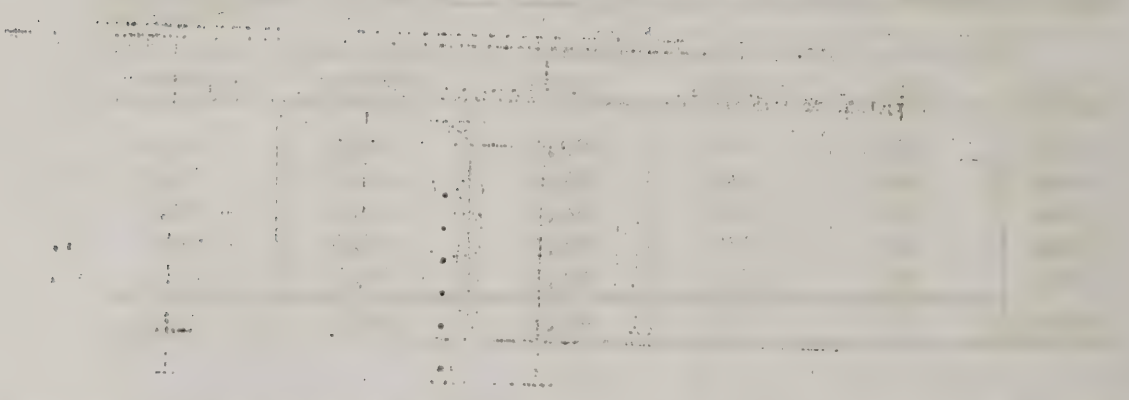
The classification of the Gibberella infected ears with respect to husk coverage is given in Table 15. In 1931 and 1932 the open infected ears exceeded in number the covered infected ears, but in each of the 3 later years the reverse was

Table 15.-- Relation of Gibberella ear rot to husk coverage, 1931-1935.

Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1931	20	9	69.0	31.0	38.0
1932	26	19	57.8	42.2	15.6
1933	10	19	34.5	65.5	- 31.0
1934	33	67	33.0	67.0	- 34.0
1935	32	118	21.3	78.7	- 57.4
Average			43.1	56.9	- 13.7

true, so that for all the years considered open ears were fewer by 13.7 percent annually than covered ears in the infected lots. This general tendency seems to indicate that perfect coverage by husks is, in fact, no protection but may be conducive to a greater abundance of infection. Such a conclusion serves, perhaps, to emphasize the already recognized importance of infection by way of the silks.

The numbers and proportions of open and covered ears among the Basisporium infected ears found each year are given in Table 16. The number of infected ears found in 1931, 1932, and 1933 was small. A definite preponderance of open infected ears occurred in 1931 and 1932, but in each of the succeeding years covered infected ears predominated to such an extent that for all 5 years they exceed by an average of 9.6 percent annually the proportion of infected open ears. In this, as in the 2



ear rots just discussed, some correlation appears to exist between closed rather than open ears and abundance of disease, indicating that full husk coverage provides con-

Table 16.-- Relation of Basisporium cob rot to husk coverage, 1931-1935.

Year	Number of rotted ears		Percent of rotted ears		Excess of open, in percent
	Open	Covered	Open	Covered	
1931	31	7	81.6	18.4	63.2
1932	12	3	80.0	20.0	60.0
1933	6	27	18.2	81.8	- 63.6
1934	33	76	30.3	69.7	- 39.4
1935	19	101	15.8	84.2	- 68.4
Average			45.2	54.8	- 9.6

ditions favoring infection; but the occurrence in 2 years of more open diseased than covered diseased ears, together with the small average preponderance of covered diseased ears indicates also a degree of independence of ear coverage. In view of the wide distribution on living and dead plant materials of the causal fungus, as well as its strong saprophytism, it may be assumed that it finds the accumulation of pollen and plant refuse held, and perhaps kept favorably moist, by long, enclosing husks especially satisfactory as a medium of primary development, from which subsequent infection may be accomplished.

Comparison of the Relations of Specific Ear Rots to Husk Coverage

While the general prevalence of ear rot, as indicated in a previous section, appears definitely correlated with imperfect coverage of corn ears, it will have been noticed in the preceding discussion of specific rots that there is no general agreement among them as to predominance of infection in either open or closed ears. With certain diseases, the preponderance of infection occurs in open ears; with others, it occurs in closed ears; and with some there is an alternation from one condition to the other in different years.

The usual relationships of infection to husk coverage, determined for each disease in previous tabulations by averaging the percentages of open and covered infected ears, and the differences between them, for the years during which each was observed, are brought together in Table 17 and are shown graphically in Figure 2. With this comparison as a basis, the 8 ear diseases can be considered to fall in 3 rather well defined groups.

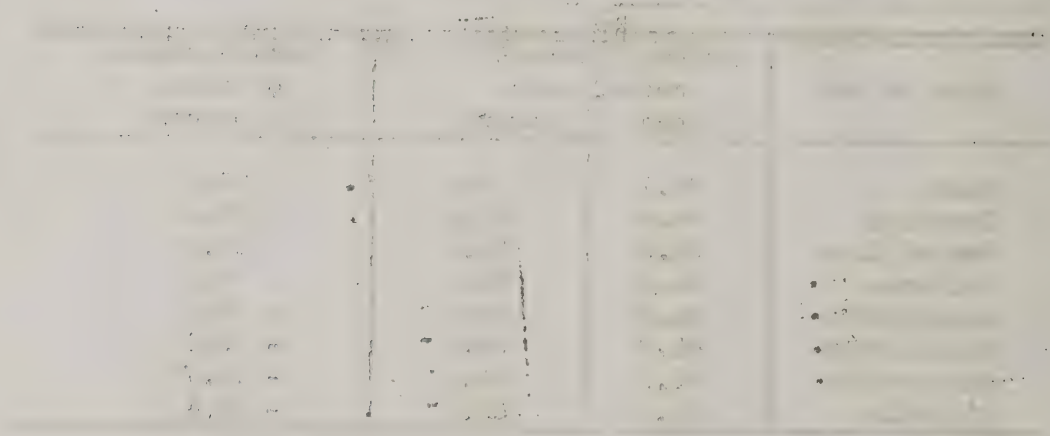
The first of these, which includes smut, Fusarium rot, and Penicillium rot, may be considered to be favored to a considerable degree by imperfect husk coverage.

Table 17.-- Summary of the relation of individual rots to husk coverage, 1931-1935.

Type of rot	Average percent of rotted ears		Average excess of open, in percent
	Open	Covered	
Smut	90.1	9.9	80.2
Fusarium	68.8	31.2	37.6
Penicillium	61.8	38.2	23.6
Rhizopus	54.6	45.4	9.2
Aspergillus	45.5	54.5	- 9.0
Basisporium	45.2	54.8	- 9.6
Gibberella	43.1	56.9	- 13.7
Diplodia	38.8	61.2	- 22.4

The second group, which includes Rhizopus, Aspergillus, and Basisporium rot, probably depends very little upon imperfect coverage for the opportunity to infect but is influenced, as suggested in Tables 11, 12, and 16, to a large extent by environmental factors or by differences in development or condition of the corn plant itself.

The third group, in which are included Diplodia and Gibberella ear rot, appears to exhibit a marked negative correlation between abundance of infection and imperfect husk coverage, since in each case a considerably greater proportion of the infected ears were well covered by husks. The significance of this is not apparent



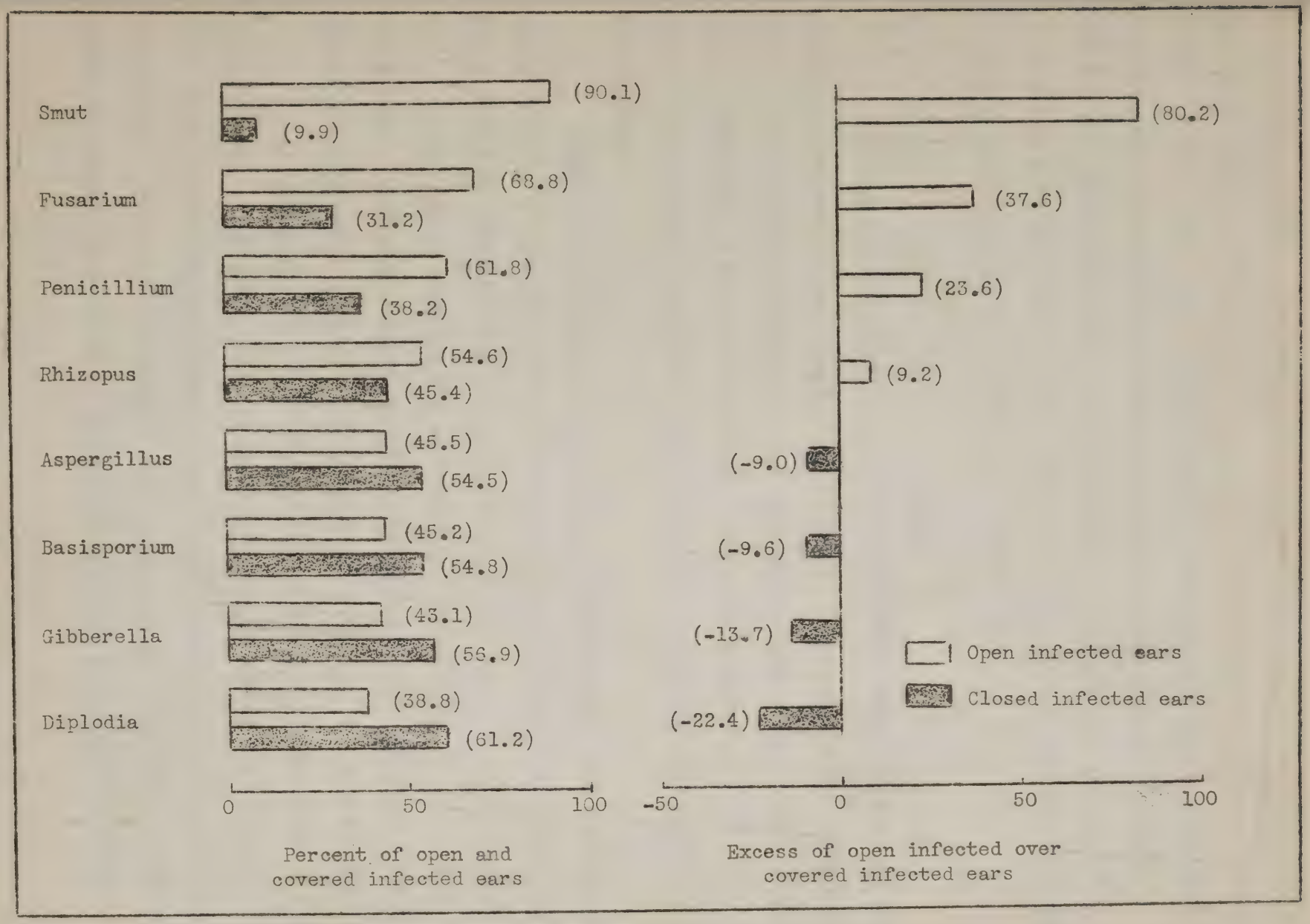
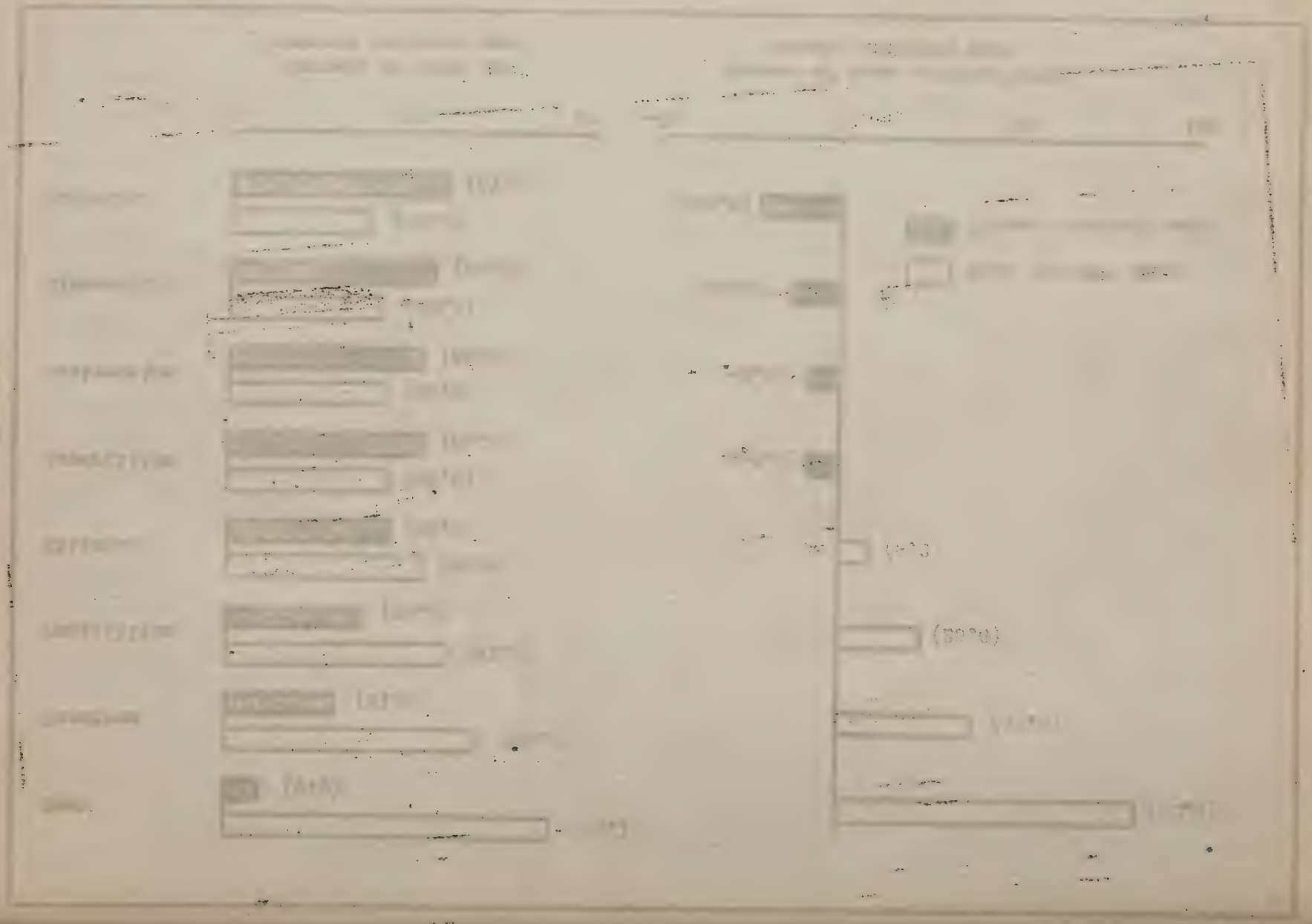


Fig. 2.-- Comparison of the proportion of open and covered infected ears in certain corn ear rots.



for the known seasonal histories and methods of infection of the fungi concerned are such as to indicate that at least as great a number of open as covered ears should become infected. The data at hand obviously indicate that well covered ears present more favorable conditions for infection by these fungi, just as open ears do for Fusarium and Penicillium; but it is not possible to say what these conditions are. It is clear, however, that in this group of rots the mechanical protection afforded by perfect husk coverage is no deterent to infection.

SUMMARY

In order to determine what relationship might exist between the field prevalence of corn ear rot and the failure of husks to enclose the ear completely, data bearing on the question have been taken in Illinois corn fields during a period of 5 years, 1931-1935. A total of 57,395 ears have been examined in 297 fields representing all parts of the state. Analysis of the data so obtained has given the following information.

Imperfect coverage of ears by husks is more common than perfect coverage. The proportion of open ears varied from year to year, ranging from 53 to 70 percent, but averaged 61 percent for the entire period. (See pp. 2 - 4 and Tables 1 and 2.)

Ear rot is surprisingly prevalent in Illinois corn fields. Data taken during 4 years, 1932-1935, show a prevalence varying in different years from 28 to 90 percent, and an average of 55 percent annually. (See pp. 4 - 5 and Table 3.)

In corn ears not completely covered by husks the prevalence of rot ranged during 3 years, 1933-1935, from 40 to 92 percent and averaged 59 percent. In ears completely covered the prevalence of rot ranged from 24 to 88 percent and averaged 49 percent. Among the rot infected ears entering into the above data those with open husks constituted from 57 to 67 percent in different years and for the entire period

exceeded the covered infected ears by 23 percent. (See pp. 5 - 6, Tables 4 - 6, and Figure 1.)

Data bearing upon identified ear rots cover 5 growing seasons and indicate the following average prevalences for this period: Fusarium, 40.7 percent; Penicillium, 5.8 percent; Rhizopus, 3.0 percent; smut, 1.7 percent; Diplodia, 1.2 percent; Gibberella, 0.72 percent; Basisporium, 0.56 percent; and Aspergillus, 0.23 percent. Classification according to husk coverage of the ears observed to be infected by each fungus indicates that infection by smut, Fusarium, and Penicillium is favored by imperfect husk coverage, that infection by Rhizopus, Aspergillus, and Basisporium probably is neither hindered very greatly by perfect coverage nor favored to any marked degree by imperfect coverage, and that infection by Diplodia and Gibberella is in some way distinctly encouraged by perfect husk coverage. (See pp. 9 - 18, Tables 7 - 17, and Figure 2.)

The fact that imperfectly covered ears predominate in Illinois corn fields undoubtedly results in a greater prevalence of ear rot and in a larger field loss than would be the case if perfectly covered ears predominated. As an attack on the general problem of ear rot control, the development of corn varieties or selections characterized by complete coverage of the ear by husks presents an interesting problem, even though the data at hand indicate that general planting of such varieties would possibly result in an increased abundance of certain rots now of relatively infrequent field occurrence.

Little is known at present regarding the nature of the relation between length of ear and length of husk. Whether husk coverage is a character that is definitely heritable or whether it is determined by the vigor of ear growth should be ascertained. Should it prove to be heritable, combining it with genetic resistance to certain diseases in high yielding varieties should result in greatly reduced loss from ear rots.

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CONTROL OF ELM DISEASES

IN

NURSERY ELM PLANTINGS

J. C. Carter

STATE OF ILLINOIS
Henry Horner, Governor
Department of Registration and Education
NATURAL HISTORY SURVEY DIVISION
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Leo R. Tehon, Botanist

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CONTROL OF ELM DISEASES IN NURSERY ELM PLANTINGS

J. C. Carter

Introduction

An investigation has been in progress in Illinois since 1931 to determine causes and possible control measures for the so-called "elm wilt." This term, used by nurserymen and others to designate any wilting of elms, regardless of cause, is so used for convenience in this paper. Several fungi have been found to cause "elm wilts"; namely, Coniothyrium, Cytosporina, Phoma, and Verticillium. A report on our tests of fungicides from 1931 to 1934 to control elm wilt was distributed in 1935 as Biological Notes No. 4.

In 1935 a reorganization of the experiments looking toward control became necessary. Of the ten plots that had been in use, 5 had to be abandoned, 3 because the trees had grown too large to be thoroughly dusted without power equipment, and 2 because the trees were then too tall to be sprayed with the equipment available.

In place of these 5 abandoned plots, 3 new plots were selected and planned to provide comparative tests of dormant sprays and of new spray materials. The new plots, started in 1935, have been under treatment 2 years.

The data given in the present report apply, as is indicated in the foregoing, to 5 plots treated continuously from 1932 through 1936 and to 3 plots treated only for 2 years.

Materials

All experiments have been conducted upon American elms located in the midst of elm blocks being grown by nurseries as regular commercial production, in

cooperation with nursery owners. Both dormant and summer sprays and dusts have been used. For the entire period 1932-1936 one copper fungicide (Corona Bordeaux) and four sulphur fungicides (Koloform, Kolodust, flotation sulphur dust, and dry wettable flotation sulphur) have been used continuously on the same trees as summer sprays. In 1935 tests were begun with two new copper fungicides (Instant Bordeaux and "Z-O") and one new sulphur fungicide (liquid lime sulphur). Instant Bordeaux and "Z-O" have been used both for dormant and for summer sprays. Liquid lime sulphur has been applied only as a dormant spray and has been followed by summer applications of Koloform and dry wettable flotation sulphur. These fungicides may be described as follows:

A. Copper fungicides.

1. Corona Bordeaux is a commercial, pre-mixed Bordeaux that only needs to be mixed with proper amounts of water to obtain required strengths. This fungicide, manufactured by the Corona Chemical Division of the Pittsburg Plate Glass Company, is composed of active ingredient (copper) of not less than 13 percent and inert ingredients of not more than 87 percent.

2. Instant Bordeaux is a recently developed Bordeaux that can be made very quickly and easily as needed by mixing blue vitriol (copper sulphate) powder and superfine hydrated lime with water in proper proportions. To prepare 100 gallons of 4-4-50 Instant Bordeaux, weigh out 8 pounds of powdered copper sulphate and 8 pounds of superfine hydrated lime. Begin filling the spray tank with water. When the tank is approximately one-fourth full, start the engine and keep it running until the tank is full. As soon as the engine is started, place the copper sulphate upon the intake strainer and wash it into the tank. When the tank is three-fourths full, place the superfine hydrated lime on the intake strainer and wash it into the tank.

Let the agitator run for approximately 1 minute after the tank is full. Instant Bordeaux is then ready to use. In general, Instant Bordeaux settles out more slowly than commercially prepared Bordeaux mixtures.

3. "Z-O," which is manufactured by the Nichols Copper Company, is a copper fungicide which contains copper equivalent to 26 percent in metallic form. It has been developed as a substitute for the Bordeaux mixture used on apples and has been found practical for general spraying of ornamentals. It can be used in dust form for truck crops. There is a gradual release of copper from"Z-O," which, it is claimed, makes it less harmful to treated plants than any other copper fungicides.

B. Sulphur sprays.

1. Liquid lime sulphur is a standard fungicide used in orchard practice. We have used it only as a dormant spray, at the strength of 1 to 10 (1 part liquid lime sulphur to 10 parts water). The fall dormant was applied in October or November and the spring dormant in March or early April.

2. Koloform is a sulphur dust, sold by the Niagara Spray and Chemical Company, which forms a spray when added to water. It is composed of active ingredient (sulphur) of not less than 54 percent and inert ingredients of not more than 46 percent.

3. Koppers Flotation Sulphur, manufactured by the White Tar Company of New Jersey, Inc., is an exceedingly fine sulphur dust which mixes readily with water and is used as a spray. It is composed of active ingredient (sulphur) of not less than 80 percent and inert ingredients of not more than 20 percent.

C. Sulphur dusts.

1. Kolodust, manufactured by the Niagara Spray and Chemical Company, is

very similar to Koloform but is applied as a dust. It is composed of active ingredient (sulphur) of not less than 87 percent and inert ingredients of not more than 13 percent. A portion of the sulphur in Kolodust and also in Koloform consists of highly colloidal sulphur produced by the adsorption of molten sulphur into Bentonite clay.

2. Koppers Flotation Sulphur Dust is similar to Koppers Flotation Sulphur but is used as a dust.

Methods

The trees received three types of treatment, and ample provision was made for maintaining untreated trees as checks against the treatments. The types of treatment were as follows:

1. Pruning: Diseased parts of infected trees in test blocks were pruned out and destroyed.

2. Fungicides: Trees in test blocks were sprayed or dusted with the proper fungicides.

3. Pruning plus fungicides: Diseased parts of infected trees in test blocks were pruned out and destroyed. After that, the trees in such blocks were sprayed or dusted with the proper fungicides.

From the beginning of the work in 1932 until the fall of 1935, applications of the liquid fungicides were made with the sprayers owned by the nurserymen at each place where a plot of trees was located. These sprayers varied from 50-gallon hand operated outfits to 100-gallon power outfits. But since the fall of 1935 all spraying has been done with a 100-gallon Bean Little Giant Duplex outfit.

The various capacities and types of outfits used at first naturally resulted in lack of uniformity of spray application in the different plots, but since 1935 this difficulty has not existed.

Sulphur dusts were applied with a Niagara blower dust gun. This gun blows a good cloud of dust to a height of 8 to 10 feet. Almost without exception, the dust applications were made in early morning when dew was on the foliage and before the wind became too strong to prevent uniform dusting.

Summer applications of fungicides have been started in May or early June each year, except in 1936 when the first summer spray was applied during the last week of April. In the early period of the work, applications were made at approximately three-week intervals. More recently, the first summer spray has been applied in early May and subsequent applications have been made every ten days to two weeks until the beginning of the dry weather period, which is usually about the middle of July. Three-week intervals between applications have been allowed after that time. Summer applications of fungicides were terminated the latter part of August.

Dormant applications of liquid fungicides were started in the spring of 1935 in 2 of the 3 new plots started that year. The practice of applying both spring and fall dormants has been followed, the fall dormant being applied in October or November and the spring dormant in March or early April before the buds opened.

Observations were made on the effectiveness of each fungicide used and on each type of practice employed. Data were recorded at regular intervals during the growing season on the prevalence of the "elm wilt." The trees in the several plots were divided into separate blocks and each block in a given plot received a different treatment. One block of trees in each plot remained untreated, and these served as a check on the various treatments employed.

Five-year Tests with Summer Treatments

The data presented in table 1 summarize the results of five years of experiment with pruning and with Bordeaux mixture (Corona), Koppers flotation sulphur, Koloform, and Kolodust.

Table 1.--Results in disease control in nursery elms obtained from 5 consecutive seasons of pruning, spraying, dusting, and pruning combined with spraying or dusting.

Plot numbers and treatments used	No. of trees originally present	No. of trees contracting disease in 5 years	Difference in favor of (+) or against (-) treatment	Percentage of control (+) or lack of control (-)*
Plot III				
Check	300	33		
Pruning	300	7	+ 26	+ 78.8
Bordeaux spray	300	38	- 5	- 15.2
Bordeaux + pruning	300	29	+ 4	+ 12.1
Plot IV				
Check	500	7		
Pruning	500	6	+ 1	+ 14.3
Koloform spray	500	9	- 2	- 28.6
Koloform + pruning	500	13	- 6	- 85.7
Plot VII				
Check	711	151		
Bordeaux spray	474	113	- 18**	- 11.9
Flotation sulphur spray	474	116	- 23**	- 15.2
Plot VIII				
Check	400	64		
Pruning	400	67	- 3	- 5.0
Kolodust	400	46	+ 18	+ 28.1
Kolodust + pruning	400	33	+ 31	+ 50.0
Plot IX-L				
Check	347	113		
Koloform spray	347	142	- 29	- 25.7

* Percentage of control obtained as follows: $\frac{\text{Treatment difference (col. 4)}}{\text{Disease in check (col. 3)}} \times 100.$

** Calculated on the basis of 711 trees in each treatment.

Pruning out diseased parts, when done without any other treatment, gave 79 percent control in plot III and 14 percent in plot IV, but failed by 5 percent in plot VIII.

A greater number of cases of wilt occurred in the blocks of sprayed trees than in the checks. Bordeaux in plot III permitted the occurrence of 15 percent more, and in plot VII 12 percent more diseased trees than occurred in the corresponding checks. With Koloform in plot IV, the number of diseased trees was 28 percent greater, and in plot IX-L 26 percent greater than occurred in the check blocks. And in the flotation sulphur block in plot VII the proportion of diseased trees was greater by 15 percent than in the check. In contrast, however, sulphur dust proved somewhat effective, Kolodust permitting the occurrence in plot VIII of 28 percent fewer cases of wilt than occurred in the check.

Results obtained when pruning was combined with fungicides proved erratic. In plot III, combined with Bordeaux, trees becoming infected were 12 percent fewer than in the check and about 24 percent fewer than with Bordeaux alone. But combined with Koloform in plot VII, pruning appears to have increased very considerably the proportion of diseased trees, in comparison with both the check and the sprayed blocks. Done in combination with dusting---Kolodust in plot VIII---it appears to have been moderately effective, the number of diseased trees being but 50 percent of the number occurring in the check block, 70 percent of the number in the dusted block, and 49 percent fewer than when pruning alone was done.

These five years of consecutive treatment indicate, on the basis of the results just stated, that so far as "wilt" control is concerned the use of Bordeaux and sulphur sprays for summer application alone tends to increase the prevalence of "elm wilt." The practice of pruning out diseased parts generally tends to reduce

the amount of disease, and the general effect of combined pruning and spraying is a decrease in the effectiveness of pruning which tends to balance the ineffectiveness of sprays. Dusting with sulphur is, however, somewhat effective and, when combined with pruning, proves the most effective among the treatments tested.

Tests with Sulphur Summer Spray and Dusts

Data in addition to those obtained from the uniform 5-year long treatments just described are furnished by plots IX-S and XIV for a sulphur spray and 2 sulphur dusts. These are summarized in table 2.

Table 2.--"Wilt" control obtained from treatment of nursery elms by pruning, by spraying and by dusting with sulphur, and by combining pruning with spraying and with dusting for various periods.

Plot numbers and treatments used	No. of trees originally present	No. of trees contracting disease	Difference in favor of (+) or against (-) treatment*	Percentage of control (+) or lack of control (-)
Plot IX-S (sprays)				
Check, 5 seasons	226	74		
Pruning, 5 seasons	250	62	+ 20	+ 24.4
Koloform, 5 seasons	217	47	+ 28	+ 34.1
Koloform, 5 seasons + pruning, 2 seasons	200	44	+ 27	+ 32.9
Plot XIV (dusts, 2 seasons)				
Check	236	84		
Pruning	218	46	+ 37	+ 41.1
Flotation sulphur	253	86	+ 4	+ 4.4
Flotation sulphur + pruning	222	28	+ 58	+ 64.4
Kolodust	235	81	+ 3	+ 3.3
Kolodust + pruning	201	53	+ 23	+ 25.6

* Calculated on the basis of 250 trees per block in plot IX-S and 253 trees per block in plot XIV.

Plot IX-S has been in operation for 5 years and the data for the check, pruning, and Koloform sprayed blocks cover the entire period. Pruning in addition to Koloform has been done for 2 years only. The most prevalent elm disease in this plot is the Coniothyrium canker. Pruning during 5 years proved about 25 percent effective and Koloform spray about 35 percent effective. The pruning of a group of the sprayed trees during the past 2 years has not materially affected the value of the spray.

Plot XIV, in progress for 2 years, provides a test of the effectiveness of sulphur dusts in the control chiefly of Phoma dieback. Neither flotation sulphur dust nor Kolodust give noteworthy control, but pruning appears to have been about 40 percent effective. With pruning and flotation sulphur combined a large increase over the effectiveness of each appears demonstrated in nearly 65 percent control. But with Kolodust and pruning combined, the 25 percent control obtained is less than that shown for pruning alone.

Two-year Tests of Dormant and Summer Sulphur Sprays

The possibility of increasing the effectiveness of sulphur sprays by supplementing them with dormant season sprays has been under test for 2 years. In plot XII, consisting of 850 trees, combinations of liquid lime sulphur as the dormant spray and dry wettable flotation sulphur and Koloform as summer sprays have given the data shown in table 3.

Outstanding is the fact that the addition of lime sulphur as a dormant spray has not tended to increase the effectiveness of summer sulphur sprays, and in this plot it is important to note that pruning, whether used alone or in combination with sprays, has tended very decidedly to increase the proportion of diseased trees.

Table 3.--"Wilt" control obtained from 2 years' treatment of nursery elms with liquid lime sulphur as a dormant spray and with sulphur as summer sprays.

Plot numbers and treatments used	No. of trees originally present	No. of trees contracting disease	Difference in favor of (+) or against (-) treatment*	Percentage of control (+) or lack of control (-)
Plot XII (sprays)				
Check	134	21		
Pruning	145	35	- 12	- 52.2
Dormant and flotation sulphur summer spray	142	26	- 4	- 17.4
Dormant, flotation sulphur + pruning	142	41	- 19	- 82.6
Dormant and Koloform summer spray	146	25	- 2	- 8.7
Dormant, Koloform + pruning	141	26	- 4	- 17.4

*Calculated on a basis of 146 trees per block.

Two-year Tests of Dormant and Summer Copper Sprays

Combined dormant and summer treatment with fungicides in which copper is the active ingredient have been attempted, in spite of the apparent ineffectiveness of commercial Bordeaux as a summer spray. In plot XII tests of "Z-O" (see p. 3), and in plot XIII tests of Instant Bordeaux (see p. 2), have been under way for 2 years. The data taken up to the present in these plots are summarized, with present indications, in table 4.

The value of both "Z-O" and Instant Bordeaux is much in doubt, the data being inconclusive. When used alone they have permitted more trees to become diseased than occurred in the untreated checks, but when combined with pruning, shown to operate unfavorably in both plots, the outcome is equivalent to no treatment at all for "Z-O" and 32 percent control for Instant Bordeaux.

Table 4.--"Wilt" control obtained from 2 years' treatment of nursery elms with dormant and summer copper sprays.

Plot numbers and treatments used	No. of trees originally present	No. of trees contracting disease	Difference in favor of (+) or against (-) treatment*	Percentage of control (+) or lack of control (-)
Plot XII				
Check	134	21		
Pruning	145	35	- 12	- 52.2
Z-O	143	28	- 5	- 21.7
Z-O + pruning	133	21	0	0.0
Plot XIII				
Check	186	37		
Pruning	181	40	- 4	- 10.8
Instant Bordeaux	178	54	- 19	- 51.4
Instant Bordeaux + pruning	186	25	+ 12	+ 32.4

*Calculated on the basis of 145 trees per block in plot XII and 186 trees per block in plot XIII.

Results

The foregoing tables and text have given detailed data derived from practical tests, conducted under actual nursery conditions, of a number of fungicides as preventives of "elm wilt." Other considerations, such as effect of treatment on growth, general health, survival, or value, have been ignored. A tree, once it became diseased, was counted out permanently, whether eventually it lived or died. Consequently the information presented deals solely with the effect of treatment upon new infection.

Because "elm wilt" is a collection of diseases, one of which may predominate in one situation or in one year and another elsewhere or in another year, experiments have been scattered among selected tree plots located at some distance from each other. This has provided opportunity for fairer tests of treatments and

Table 5.--Recapitulation of data on the effectiveness of treatments in preventing the occurrence of "wilt" diseases in nursery elms.

Treatment	No. of blocks of test trees used	Total number of trees in test blocks	Percentage of control (+) or lack of control (-)		
			Least	Greatest	Average*
Pruning	7	1994	- 52.2	+ 78.8	+ 17.2
Copper sprays					
Commercial Bordeaux	2	774	- 15.2	- 11.9	- 13.2
Commercial Bordeaux + pruning	1	300	--	+ 12.1	+ 12.1
Instant Bordeaux	1	178	- 51.4	--	- 51.4
Instant Bordeaux + pruning	1	186	--	+ 32.4	+ 32.4
Z-O	1	143	- 21.7	--	- 21.7
Z-O + pruning	1	133	--	0.0	0.0
Sulphur sprays					
Flotation sulphur	1	474	- 15.2	--	- 15.2
Koloform	3	1066	- 28.2	+ 34.1	- 14.8
Koloform + pruning	2	700	- 85.7	+ 32.9	- 51.8
Lime sulphur and sulphur sprays	2	288	- 17.4	- 8.7	- 13.0
Lime sulphur and sulphur sprays + pruning	2	283	- 82.6	- 17.4	- 50.1
Sulphur dusts					
Flotation sulphur	1	253	--	+ 4.4	+ 4.4
Flotation sulphur + pruning	1	222	--	+ 64.4	+ 64.4
Kolodust	2	635	+ 3.3	+ 28.1	+ 18.9
Kolodust + pruning	2	601	+ 25.6	+ 50.0	+ 41.8

* This average is obtained by weighting data from individual blocks in proportion to the number of trees in the blocks.

has permitted the performance of certain tests in more than one locality. Since any treatment recommended as effective should prove itself to be so in any locality, the data from individual plots should be considered from that point of view.

A recapitulation of the essential data furnished by the plot tests is given in table 5. Both the number of plots in which each treatment was tried and

the total number of trees upon which it was tested are given, as are also the least and greatest degrees of prevention obtained. In determining average effectiveness, plot data have been weighted, whenever possible, in terms of the number of trees in the tree blocks concerned. In such cases the indexes of average control given in the table are considered to be more fairly expressive of the values of the treatments.

A casual inspection of table 5 will leave 3 outstanding impressions; namely, that more than half of the treatments appear to have no value, that not all the treatments that do have value give consistently positive results, and that the degree of effectiveness demonstrated by effective treatments often is disappointingly low. However, certain treatments negative as to their averages, have positive value under some conditions, and a few of the effective treatments have positive averages sufficiently high to indicate definite, practical usefulness.

A visual comparison, based on the averages given in table 5, of the effectiveness of tested treatments is shown in figure 1, in which bars reaching to the right represent effective and bars reaching to the left ineffective treatment, the length of the bars representing the percentage of control or lack of control.

By examining this diagram it may be seen that those treatments for which effectiveness has been demonstrated include (1) pruning, (2) copper sprays supplemented by pruning, (3) sulphur dusts, and (4) sulphur dusts supplemented by pruning. Those demonstrated to be ineffective include (1) copper sprays, (2) sulphur sprays, and (3) sulphur sprays supplemented by pruning.

A definite basis appears to have been demonstrated for judging the effectiveness of any treatment. It will be noted that all the treatments extending on the positive side in figure 1 involve either pruning or dusting and that, without

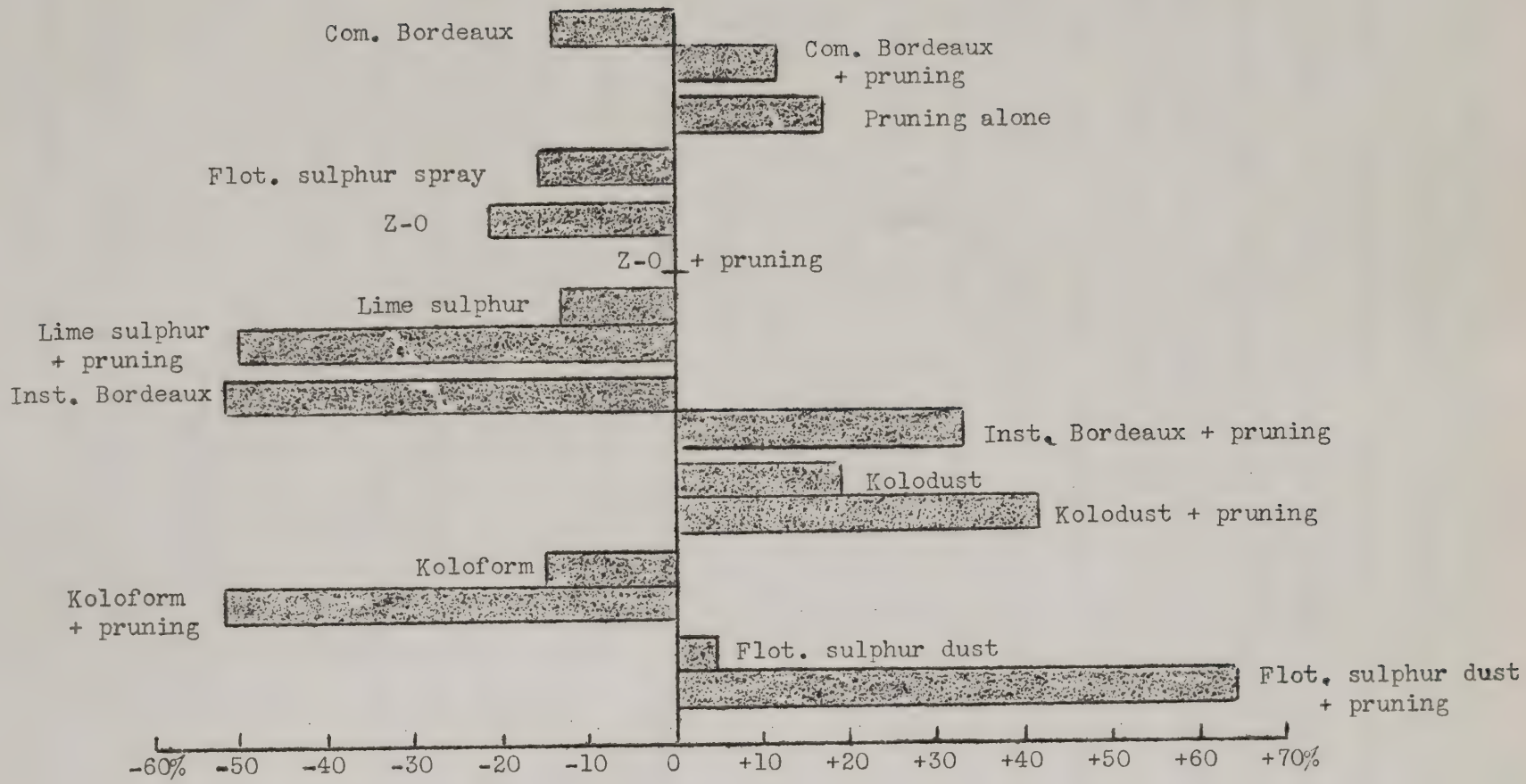

Fig. 1.--Comparison of control (+) and lack of control (-) shown by treatments tested for the prevention of "elm wilt" in nursery plots.

exception, those extending on the negative side are sprays.

The role played by pruning as a supplement to other treatments appears to be very important. Although not always dependable and as an average very moderately effective by itself (see table 5), pruning has a fairly consistent beneficial effect. It tends to increase the effectiveness of treatments which are themselves effective, as is the case with Kolodust and flotation sulphur dust, and it tends to lend value to treatments in themselves ineffective, as in the case of commercial Bordeaux and instant Bordeaux sprays. On the other hand, when used to supplement sulphur sprays it has increased greatly the ineffectiveness of these apparently ineffective sprays.

Commercial Bordeaux mixture and pruning, as a unit of treatment, is not sufficiently effective to justify its use merely for disease prevention, and the same may be said of pruning when used alone. Instant Bordeaux mixture, when combined with pruning, holds considerable promise but needs more adequate testing. Both Kolodust and flotation sulphur dust are effective to a small degree when used alone, and in both cases this inherent effectiveness is increased in greater than expected proportions by supplementing the fungicides with pruning.

Although certain differences in results will be found between this and the prior report, the main conclusion remains the same. Summer applications of sulphur dusts are the only treatments that have served consistently to prevent new infections of "elm wilt," and the effectiveness of even these treatments is very greatly enhanced by concurrent pruning.

Recommendations

As previously reported and as stated herein, our results point definitely to summer use of sulphur dusts for the prevention of the "elm wilt" disease in

nursery plantings and indicate strongly that pruning out diseased parts of infected trees is a necessary supplement to the dusts if adequate prevention is to be secured. It has been noticed that healthy nursery elms grow more rapidly if they are treated with a fungicide several times each season. Since both copper sprays and sulphur sprays and dusts stimulate growth, and in this respect repay their cost, quite apart from the disease control they effect, the use of a fungicide is always desirable.

Instructions

Sulphur dusts should be applied with a power duster, in order to develop a dust fog sufficient to cover all portions of trees being treated. Trees up to 10 feet in height can be treated with a small, hand power duster. However, this is much slower and less satisfactory than a more powerful outfit. It is desirable to dust in earlymorning or just after a light rain, while moisture is still on the foliage and when the air is nearly still. For best results, application of dusts should be made at regular intervals and frequently enough to maintain a complete protective covering on the foliage and wood. The new leaf growth that develops continually throughout the growing season should receive as much protection as possible. In most cases, dusting at two-week intervals during late April, May, and June, when rains are most frequent, and at three-week intervals during July and August will reduce the number of new wilt cases which may occur during any one season and will at the same time give adequate control of leaf spot diseases.

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State of Illinois
Henry Horner, *Governor*

LAKE MANAGEMENT REPORTS

1. Horseshoe Lake near Cairo, Illinois

David H. Thompson
and
George W. Bennett

Department of Registration and Education
John J. Hallihan, *Director*

Division of the Natural History Survey
Theodore H. Frison, *Chief*

Biological Notes No. 8 Urbana, Illinois September, 1938

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LAKE MANAGEMENT REPORTS

1. Horseshoe Lake near Cairo, Illinois

David H. Thompson and George W. Bennett
Illinois Natural History Survey

For many years the Illinois Natural History Survey has been measuring fish populations and fish production. Among the various types of Illinois waters studied, it has been found that each tends to have the capacity to support a certain number of pounds of fish per acre which is constant from year to year. This number of pounds per acre remains constant even though there may be ten times as many fish (of one-tenth the average weight per fish) in some years as in others. When this amount of fish flesh per acre is disturbed by putting in or taking out fish or by floods or drouths, readjustment takes place much more rapidly than is popularly supposed.

When a new lake is stocked with a few breeder fish the saturation point is usually reached in about a year. When one-fourth, or less, of the total amount of fish in a lake is removed during the course of a season, readjustment takes place so rapidly that changes in abundance are not detectable. This means that the yield of game fishes from an acre of water can be many times the amount taken out by ordinary fishing.

Fish grow to more desirable sizes and furnish a better quality of food and sport when their numbers are reduced enough to give rapid growth rates. Good farmers understand this view of livestock and crop production and practice it continually. The following is an account of the changes which have taken place in Horseshoe Lake since its reconstruction in 1931.

Description

Horseshoe Lake embraces about 2,400 acres of water with a 1,400-acre island in the center. The Illinois Department of Conservation owns the island and about two-thirds of the water surface and maintains it as a waterfowl refuge. The lake is located about 12 miles northwest of Cairo on Highway 150.

Horseshoe Lake is part of a former channel of the Mississippi which has grown up in cypress. Cypress, gum, willow and buck brush grow throughout all parts of the lake, although the trees are more scattering along the east side, leaving considerable areas of open water. With the exception of some flooded pasture lands, the remainder of the lake is grown up in timber and brush. The east side of the lake has a uniform depth of about six feet; the remainder is

KINDS, SIZES AND NUMBERS OF FISH IN HORSESHOE LAKE

Kind	Total No. Handled 1934-38	Average Total Length in Inches				Estimated Number in Lake during the Past Year
		1934	1936	1937	1938	
Largemouth Bass	235	12.4	16.2	15.4	16.2	5,000 to 10,000
White Crappie	1,044	10.3	10.7	10.9	8.5	250,000 to 350,000
Black Crappie	3,913	6.3	7.9	7.6	7.9	500,000 to 700,000
White Bass	3					
Yellow Bass	15					
Warmouth Bass	9					
Bluegill	969	7.3	6.9	6.8	6.8	150,000 to 250,000
Green Sunfish	2					
Flier Sunfish	825	5.3	6.0	5.8	5.9	4,000 to 15,000
Grass Pike	14					
Spotted Gar	2					
Dogfish	17					
Channel Cat	9					
Black Bullhead	1,122	9.1	10.0	10.5	11.1	150,000 to 250,000
Yellow Bullhead	329	10.8	10.9	12.1	11.4	35,000 to 50,000
Gizzard Shad	1,244	9.1	9.7	10.4	10.7	50,000 to 200,000
Golden Shiner	11					
Carp	217	19.8	20.8	21.5	22.6	25,000 to 50,000
Redmouth Buffalo	618	13.8	17.0	17.9	18.1	25,000 to 100,000
Mongrel Buffalo	33	15.2	20.3	22.7	21.7	1,000 to 5,000
Smallmouth Buffalo	12					
Quillback	9					
Redhorse	1					
Spotted Sucker	139	12.9	16.2	16.8	17.7	5,000 to 20,000
Chub Sucker	1					
Total	10,793					1,200,000 to 2,000,000

(Left)
Cypress Trees Grow in the Open Waters of the Lake

(Right)
Don Hansen Measures a Carp at the Ferry Landing

more shallow with depths ranging from one to six feet.

A small creek about 25 feet wide feeds Horseshoe Lake from a large area to the north and east. In addition, a dredge ditch about six feet deep drains the hills from the north and west. During heavy rains these streams bring in a great deal of muddy water which often extends well down the lake. Although Horseshoe Lake is brownish in color, it is sufficiently transparent to allow bottom to be seen in one to three feet of water. Submerged aquatic vegetation is scanty.

The climate of this southern tip of Illinois is much milder than most upstate citizens realize. Cotton is grown in this vicinity; mistletoe parasitizes the elms and maples; and cane brakes are scattered in the lowlands. The fish have a growing season nearly twice as long as that of northern Illinois and pole-and-line fishing goes on throughout most winters.

History

In 1930 the old dam holding Horseshoe Lake washed out. The lake drained and lay completely dry for a year. The only water left was in the dredge ditch which feeds the lake. A permanent dam of concrete with deep foundations was built in 1931. Rains in late summer and early fall of that year partially filled the lake. In December, 1931, a stock of small bass, crappies, bluegills, channel cat, bullheads, small carp and buffalo were brought from the Illinois River at Havana and put in Horseshoe Lake. This was followed by some larger bass stocked in the early spring of 1932. Apparently a few other kinds of fishes survived the draining of Horseshoe Lake in the pools of the dredge ditch. The most important of these were the flier sunfish, the spotted sucker, and three species of forage fish—the live-bearing top minnow (*Gambusia*), the golden shiner and the gizzard shad.

Fish Surveys

Zoologists of the Natural History Survey have watched the course of events in Horseshoe Lake each year since it was rebuilt. In 1934, 1936, 1937 and 1938, a crew of men, outfitted with boats, nets and a miscellany of scientific equipment, caught, identified, measured, weighed and took scales from large numbers of fish. This information has made it possible to estimate the abundance of the important species in the lake, their rates of reproduction, rates of growth and death rates.

The first three of these surveys were made by Mr. Francis D. Hunt, then field naturalist for the Natural History Survey. In order to make the fishing methods for all years as uniform as possible, Mr. Hunt, who is now fish culturist for the Department of Conservation, assisted in making the 1938 survey.

Twenty-five kinds of fish were taken in hoop nets during these four surveys. Eleven of these kinds represent one percent or more of the total. A list of species and the numbers taken is shown in the accompanying tabulation, along with average lengths for each year of the more abundant kinds. From year to year the same nets were used and set in about the same places in the lake. As these nets were one-inch mesh, the small fish, up to a size of about four inches in circumference, escaped.

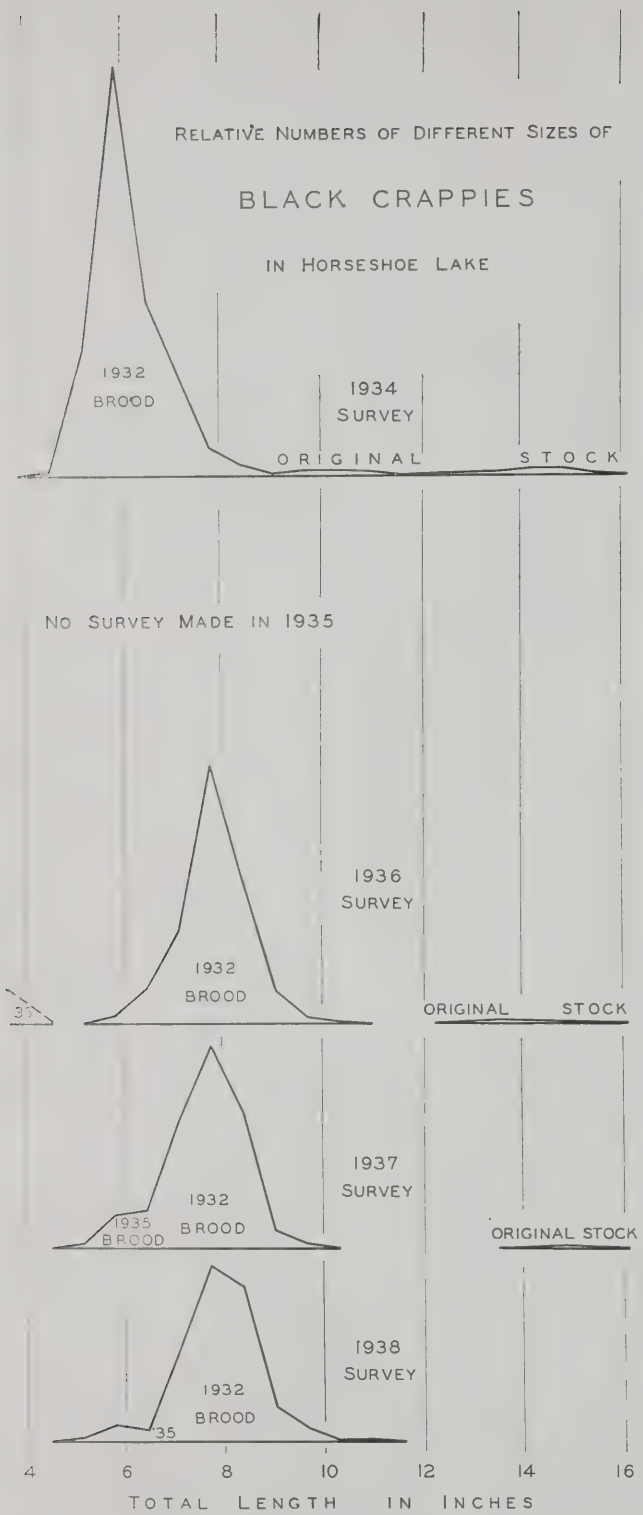
The same nets were used in the years 1932-1937 to catch fish for the population measurements in the lakes of the Illinois Valley. There it was found that in the warm weather of spring and summer each net caught the fish from about one-tenth of an acre in one day. The total number of fish taken during these four surveys in Horseshoe Lake represents the catch from about 20 acres of water. This makes it possible to estimate within certain limits the total number of individuals in the lake of each of the more common species. Certain kinds of fish are caught in these nets much more readily than others. These differences in behavior have been taken into consideration in estimating the total numbers shown in the tabulation.

Estimates of Total Poundage

At the present time it is estimated that Horseshoe Lake is supporting about 150 pounds per acre of bass, crappies and sunfish. The bullheads amount to an additional 65 pounds per acre. In addition to the above fish which may be taken readily on hook and line, there are probably about one-half million pounds of carp and buffalo, or about 200 pounds per acre. It appears that the total of all kinds of fish of edible sizes in the lake is about one million pounds or 400 pounds per acre.

The 1937 Flood

In late January and early February, 1937, the Ohio River flooded, covering a large part of several southern Illinois counties. The flood water backed up Bay Creek a few miles, cut across to Cache River, following its valley across the southern tip of the



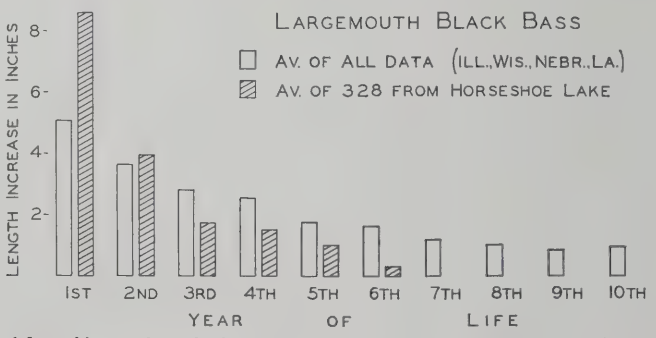
Left.—The black crappie made up 37 percent of all fish taken in hoopnets by the four surveys, 1934-1938. A huge brood of black crappies was spawned in the spring of 1932 from breeding stock placed in the lake a few months earlier. This brood grew at a normal rate during its first two years, reaching an average total length of 6 inches by the spring of 1934. After that, growth was retarded by dwindling food supplies. These fish reached an average length of 8 inches by 1936 and since then have not grown at all. Moderate reductions in the numbers of this 1932 brood from year to year have not resulted in increased growth among the survivors because of increasing competition by the white crappies. The black crappie, more than any other fish, has been responsible for destroying the young, not only of its own kind, but also those of most other species in the lake.

state. Near Horseshoe Lake this water left the channel of the Cache to enter the Mississippi at Dog Tooth Bend. At the time of the flood it seemed likely that Horseshoe Lake might have lost a large part of its fish or that objectionable species might have moved in. The 1937 survey was made to determine what changes the flood had made. We found no evidence that Horseshoe Lake had lost any of its fish. The only intruders were two spotted gars. Up to this time this species had not been taken in the lake, although it is present below the spillway. No spotted gars or other newcomers were caught in this spring's survey. If this flood had taken place in warm weather when fish are active, it seems certain that the fish population of Horseshoe would have been greatly disturbed and mixed up. Throughout the early part of the flood, the quieter waters were covered with ice and at no time did the temperature rise more than a few degrees above freezing. It appears that the fish of Horseshoe and vicinity lay quietly while the flood waters rose and went down again.

Largemouth Black Bass

Two of the diagrams show the essential facts about the largemouth bass in Horseshoe Lake.

When the lake was visited in May of 1932, as many as a quart of *Gambusia* could be taken in a short haul with a minnow seine, together with bass fry about an inch long and large numbers of fry of the flier sunfish. The top minnows and the fry of the flier sunfish probably made up the bulk of the food of the bass that first year and were responsible for their rapid growth. When the lake was visited in the summer of 1933 it was noted that the bass were growing very rapidly. The decline in the



After Horseshoe Lake was rebuilt, food was at first abundant. The bass responded to this favorable condition more readily than other species and grew very rapidly. At an age of one year they were almost twice as long and weighed six times as much as the average yearling bass in the Mississippi Valley. Increasing competition by crappies reduced growth in the bass to normal in their second year, then below normal, finally almost to zero. At the present time these bass are living on a subsistence basis.

rate of growth and the reduction of the number of bass has resulted from competition and predation by the crappies, as well as from fishing. Hook-and-line fishing has apparently removed a larger percentage of the bass than of the crappies. In June, 1934, a group of wardens under the direction of Chief Inspector Erio contacted 2,097 fishermen and enumeraated their catch during the first three days of the first open season. Their catch included 2,544 bass, but only 74 crappies. This is because bass seem to bite better than crappies in summer. The growing scarcity of bass in this lake does not seem to be due to their failure to spawn or to lack of spawning places.

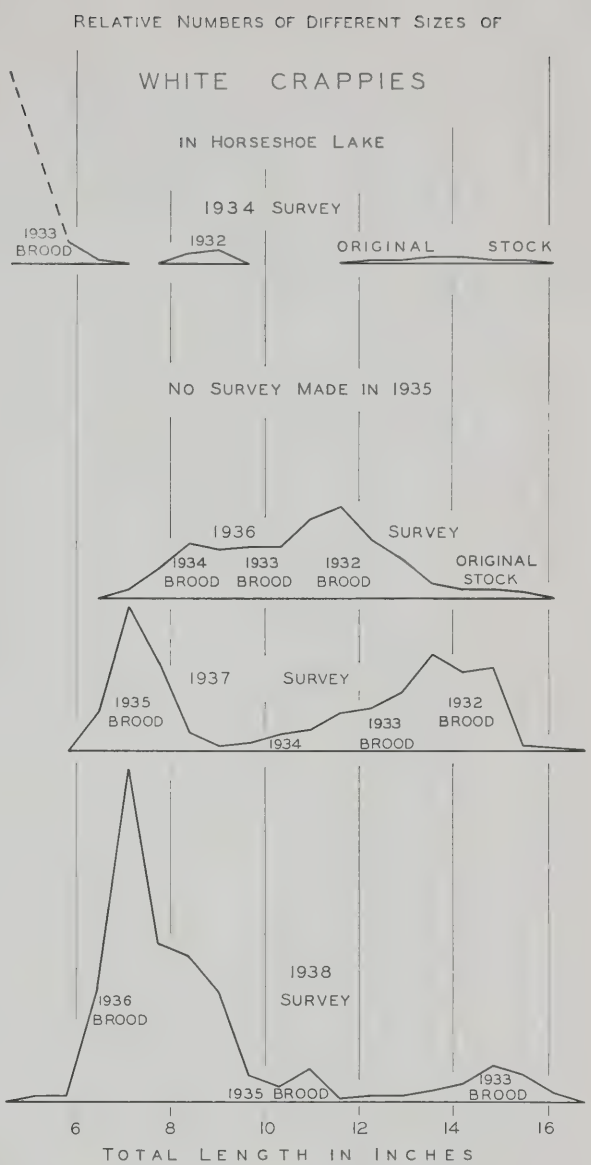
The best way to reestablish the bass in satisfactory numbers would seem to be (1) to relieve them from competition and predation by taking out more crappies and (2) to plant bass too large to be swallowed by crappies.

Crappies

Crappies made up 46 percent of all the larger fish taken in the four surveys. The facts about their growth and numbers are shown in the accompanying diagrams. Of the very large carnivorous fishes, the white crappie is most numerous. It may be noted that the decline in abundance of bass has taken place at the same time as a corresponding increase in the number of white crappies.

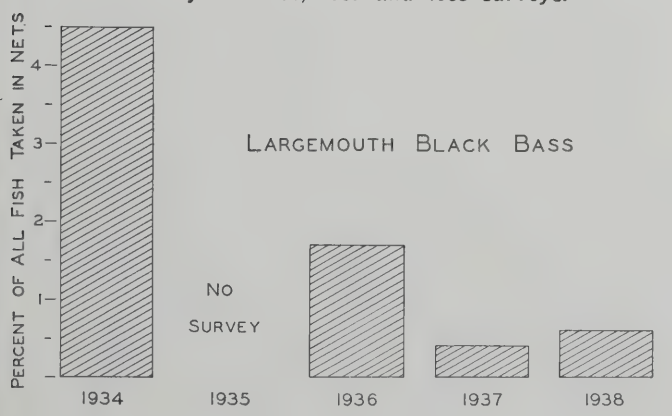
Within the past few years, larger crappies of both species have been caught or handled in Horseshoe Lake than in other Illinois waters in recent decades. A few of the very largest of these have been identified as hybrids between the two species. The largest hybrid was 17.1 inches long and weighed 4.3 pounds. It was caught in March, 1936.

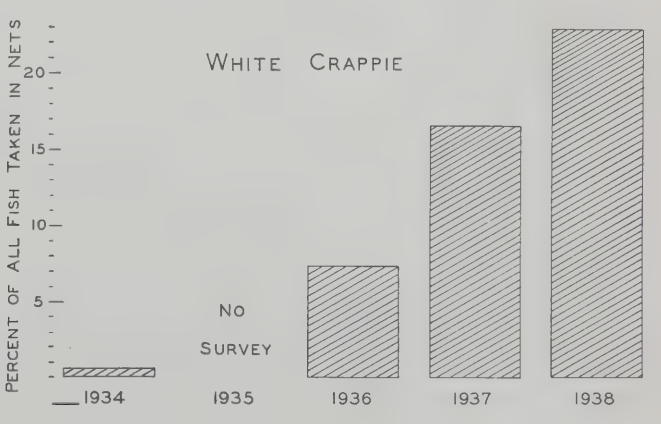
Fishermen have noticed that large specimens of most kinds of fish are usually females. For example, 23 out of 27 of these large white crappies were fe-



Below.—In the spring of 1932 the breeder bass previously placed in the lake spawned successfully. In the absence of many predators a large part of this brood survived. At the same time a large brood of crappies was also produced and survived. In succeeding years the bass spawned, but nearly all of the young have disappeared—probably eaten by the crappies. In each year since 1934, the number of legal-sized bass has been reduced to one-half or two-thirds of the number present the preceding year. The original 1932 brood still makes up over 90 percent of the bass population as shown by the 1936, 1937 and 1938 surveys.

The white crappie, in contrast to the largemouth bass and the black crappie, produced a rather small brood in 1932 when the lake was new. Unlike these other species, it has produced moderate-sized broods each year which have escaped destruction. This has resulted in a progressive increase in their numbers which is shown in the diagram below.





males. This does not mean that the female grows faster, but that the male dies off sooner.

Bluegills and Other Sunfish

The bluegill, more than any other species in the lake, has maintained a uniform population and a uniform size. It grows steadily and, apparently, reproduces successfully year after year. The bluegill does not feed on other fishes extensively, probably because of its small mouth, and is in the position of a bystander in the struggle among the crappies and the bass.

The flier sunfish multiplied rapidly during the first year and in 1934 constituted about one-fifth of all fishes taken. Since then it has declined and has almost disappeared. Only five were taken this year.

A few other kinds of sunfishes and related species have been taken in small numbers each year. None of them shows any indication of reaching important numbers, with the possible exception of the yellow bass.

Bullheads

The black bullhead spawned very successfully in 1932. This brood reached an average length of 9 inches by 1934. Since that time they have been growing one-half inch per year. There is no evidence of the survival of any subsequent broods. In April, 1937, the black bullheads were all thin. They seemed to be "all head and tail." Their flesh was extremely soft and, on dressing, much of it pulled off with the skin. During the present spring most of them seemed to be in good condition although a few were still poor.

The yellow bullhead also produced a large brood in 1932. Since then small broods have survived about every second year. The yellow bulheads also appeared to be starved in 1937, but not in 1938. A few were examined post mortem in 1937 but no evidence of disease or parasites was found.

Bullheads are desirable food and it would seem a good thing to make better use of those in Horseshoe Lake.

Forage Fish

There appear to be about one-half million pounds of game fish and bullheads in Horseshoe Lake which feed almost entirely on fish. Experiments have shown that at moderate temperatures a largemouth bass must eat about one percent of its weight in fish per day in order merely to maintain its bodily processes, without any increase in weight. Since there are about 200 days a year when the water of Horseshoe Lake is warm, this means that one million pounds of forage fish are the minimal sustaining requirements for these fish. Growth of these game fish demands nourishment at the rate of 3 to 5 pounds of forage fish for each pound of new flesh added. Thus, it is not improbable that as much as two or three million pounds of small fish are consumed annually.

The principal items which compose this enormous quantity of fish flesh are:

(1) The young of larger fishes.

(2) Both young and adults of a variety of minnows and other small fishes, of which the golden shiner and the live-bearing top minnow have been of outstanding importance.

(3) The gizzard shad.

The gizzard shad, while not useful for human consumption, multiplies very rapidly and is an important food for game fish in lakes. It has a further advantage in that it feeds upon the microscopic life in the water and does not compete for food with edible species. From 1934 until 1937 the number of adult gizzard shad declined steadily, probably because they were eaten by increasing numbers of crappies of large sizes. Now that the large-sized crappies are disappearing, the gizzard shad again shows an increase.

Rough Fish

The carp and buffalo which make up the bulk of rough fish in the lake now average about 5 pounds each. Each female carp of this size produces one-half million or more eggs. The young fish which develop from these eggs are an important food item of the game fish and tend to offset whatever competition the carp and buffalo offer in other respects.

NOTE:—Reprinted in part from Illinois Conservation, Summer, 1938. Cuts and type courtesy of Illinois Department of Conservation.

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(63389)

STATE OF ILLINOIS

Henry Horner, Governor

DEPARTMENT OF REGISTRATION AND EDUCATION

John J. Hallihan, Director

LAKE MANAGEMENT REPORTS

2. Fork Lake near Mount Zion, Illinois

David H. Thompson

and

George W. Bennett

NATURAL HISTORY SURVEY

Theodore H. Frison, Chief

Biological Notes No. 9 Urbana, Illinois January, 1939

2. FORK LAKE NEAR MOUNT ZION, ILLINOIS

David H. Thompson and George W. Bennett
Illinois Natural History Survey

Fork Lake was built in 1920 by Mr. Paul S. Smith for waterfowl, hook-and-line fishing and other recreational uses. Since its establishment, the lake has been used by large numbers of waterfowl during their spring and fall migrations. As many as 25,000 ducks have visited this pond during the course of a season.

Soon after the lake was made, it was stocked with fish and for a few years furnished excellent catches of bass and other "fine" fish. Later, in spite of heavy stocking, hook-and-line fishing became very poor. During the past year or two the lake appeared to be crowded with small black bullheads. Golden shiners and small sunfish were also known to be present. Occasional evidence was seen of large "rough" fish which would not take the hook.

We recommended that all of these fish be removed and the lake restocked with largemouth bass and bluegills. Since the lake could not be drained readily, the fish were poisoned, June, 1938. A complete census of the fish present was made at this time. This census is especially significant because, very few fish having been removed in recent years, it shows the carrying capacity of such waters for fish.

After the fish were removed the water became clear. Within two weeks the lake was restocked with largemouth bass fry and adult bluegills. The bluegills spawned throughout the summer and their fry have been an important food for the bass. These bass have grown very rapidly and some of them should reach legal length by the time they are a year old.

ACKNOWLEDGMENTS

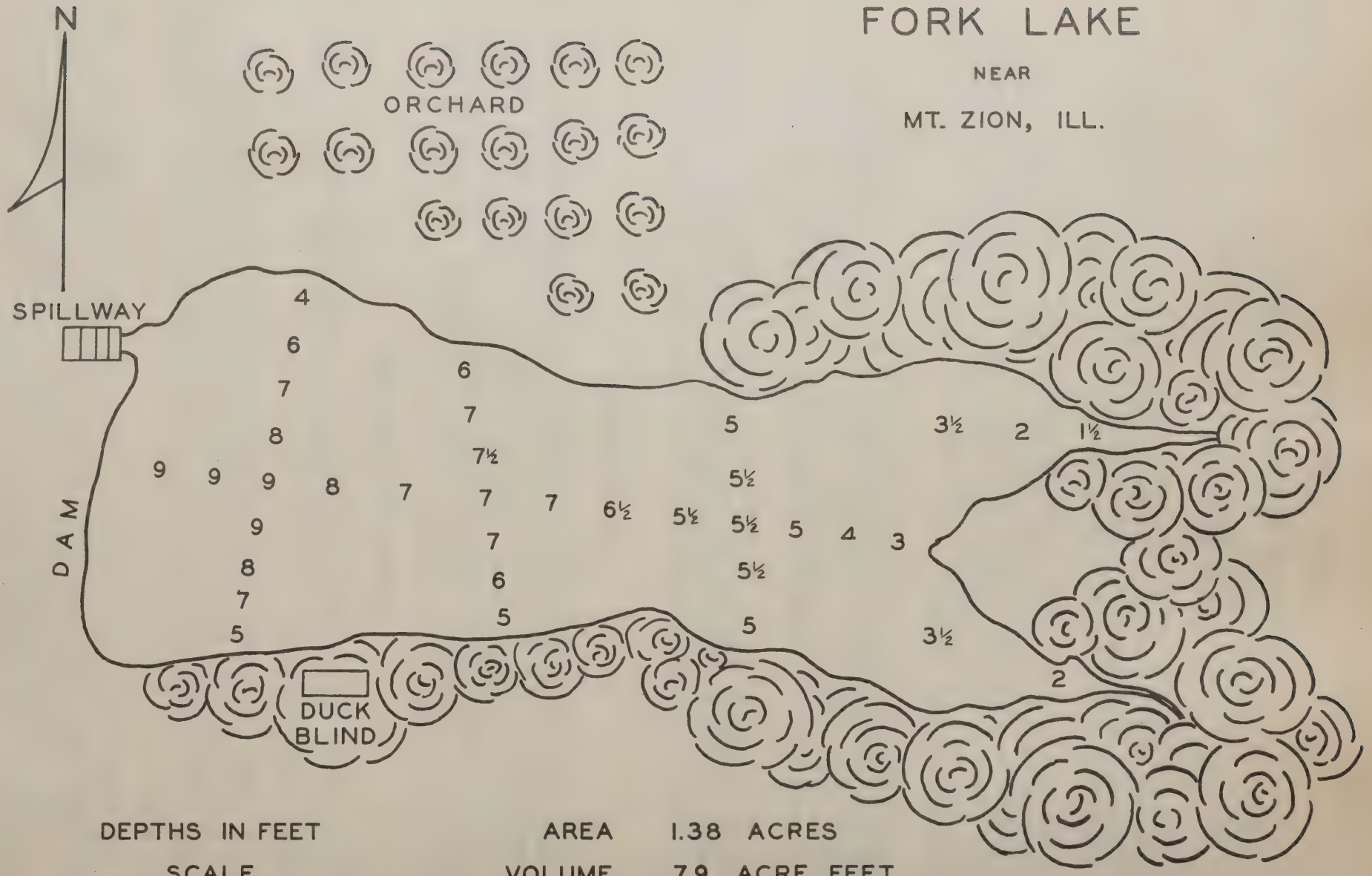
Mr. Smith furnished a great deal of the information in this report and, together with Mr. Sam A. Parr of the Conservation Department and Dr. Donald F. Hansen of the Natural History Survey, helped in all stages of the work. When the census was made, we were assisted by a number of people from the Department of Zoology of the University of Illinois. Mr. Louis A. Krumholz of the Survey made the map. The view of the lake is from a photograph by Mr. James S. Ayars, editor for the Survey. The duck pictures were taken from a blind by Mr. Smith a number of years ago.

DESCRIPTION OF THE LAKE

Fork Lake was formed by throwing an earthen dam across a ravine. It is fed by surface drainage from about 60 acres, part farmland and part timber. The soil is a tight, light-colored clay loam.

In June, 1938, at the time the accompanying map was made, the water surface of the lake was 5 inches below the crest of the spillway. The water area at that time was 1.38 acres. The maximum depth was 9 feet. The average depth was 5.7 feet, and the capacity 7.9 acre feet. According to Mr. Smith, there is now about 4 feet of silt in the lower end of the lake.

The dam is 120 feet long. The spillway is 12 feet wide and 20 feet long. The water descends in four steps, the highest of which is 3 feet. The height of these steps is of some interest since it seems likely that, during freshets, carp and buffalo may have ascended the stream and jumped the spillway into the lake. The lake has not suffered extreme shrinkage during drought years. During the drought of 1930, the water level fell about 3½ feet below the crest of the spillway.


FORK LAKE
NEAR
MT. ZION, ILL.
N
ORCHARD
SPILLWAY
DAM
DUCK BLIND
4
6
7
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9
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9
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6
7
8
7½
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5½
5
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9
8
7
6
5
5
5
5½
3½
2
DEPTHS IN FEET
SCALE
100 FEET
AREA 1.38 ACRES
VOLUME 7.9 ACRE FEET
SHORELINE 0.27 MILE

The dam is faced on the lake side with strips of metal roofing and woven wire held in place by metal posts. This has prevented damage by muskrats and ducks. In August, 1938, the dam and spillway were raised 18 inches.

The upper half of the lake and the south shore are screened by a dense fringe of brush and trees. On the slope above the north shore is a fruit and nut orchard. No submerged aquatic plants are present in the lake. At one time cattails grew all around the lake shore, but by 1938 there were only a few. Bass have been seen nesting on their roots. Most of the cattails died during low water after the ducks had exposed the roots, allowing them to freeze.

In the brush on the south side is a blind for observation, photography or shooting. There is one boat.

HISTORY OF FISH POPULATION

Fish were planted in Fork Lake a number of times before 1938. There are no records of these plantings, but Mr. Smith has furnished the following account from memory.

The earliest planting of fish, made in 1920 soon after the lake had filled, consisted of shiners, chubs and a few miscellaneous sunfishes collected from nearby streams. In 1921 several hundred largemouth bass, bluegills and other sunfishes were placed in the lake. Four hundred 6- to 7- inch bass were planted the following year (1922). Shiners and chubs were seined from nearby streams to serve as food for these bass. Bullheads were first introduced in 1924 when a school of them was brought in from Finley Creek. The first crappies were put in this same year.

During these early years, bass fishing was good* and remained so for three or four years after the original stock had reached legal length. The largest bass taken from the lake during this period weighed 2-1/2 pounds. By 1926 good catches of bullheads were being taken on trotlines. A summer or two later (1927 or 1928) many large bullheads died (apparently from lack of oxygen) along with a few shiners and sunfishes.

In 1932, 100 channel catfish were planted and, in 1934, 32 crappies, 11 to 12 inches long. In 1935, 12 large bass and a number of bluegills were added. No stocking has been done since 1935, until in the summer of 1938.

In 1935, 8 or 10 large schools of young bullheads were frequently seen swimming near the surface. The bullheads of the 1938 census probably belonged to this large 1935 brood.

Carp and buffalo were never planted intentionally. It is possible that they ascended the spillway during high water, or were introduced accidentally by anglers.

It is interesting to compare the kinds and numbers of fishes planted with those found when the lake was poisoned. The 32 large crappies planted in 1934 had not been taken out on hook and line nor had they been seen dead in the lake. One hundred channel catfish were planted in 1932. The census shows only four channel cats. Although hundreds of bass were planted, the total count was five at the time of the poisoning. The 12 large bass put in three years before were not removed by fishermen nor seen dead along the shore. The fish not accounted for probably died one at a time and were eaten by other fish, crayfishes, turtles, predatory birds or mammals without coming to the attention of occasional visitors to the lake.

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* See Thompson, David H., and George W. Bennett, 1938. Lake Management Reports 1. Horseshoe Lake near Cairo, Illinois. Ill. Nat. Hist. Surv. Biological Notes No. 8.

FISH PREDATORS

A few animals prey on the fish of Fork Lake. Snappers and painted turtles migrate up the creek to the spillway and climb the dam. The numbers of both turtles and snakes have been kept down by shooting. Bullfrogs were fairly common a few years ago, but only two were seen or heard this year. The belted kingfisher, the little blue heron, the great blue heron, the little green heron and several kinds of ducks visit the lake each year and probably eat a few fish. A flock of little blue herons (in the white phase) roosted in the low trees at the upper end of the pond for several summers.

DUCKS AND DUCK HUNTING

Even before Lake Decatur (3 miles northwest of Fork Lake) was built, ducks visited ponds and marshes near the town of Warrensburg (17 miles northwest of Fork Lake), and similar areas southeast of Mount Zion. Between them was a natural flyway or duck "pass." Later these marshy areas were drained and the flyway broken up, but it has been reestablished with the construction of Lake Decatur and Fork Lake.

Ducks were shot on Fork Lake between the years 1923 and 1933 by six men from Decatur and Mr. Smith. The pond was baited with corn, and the ducks moved back and forth between it and Lake Decatur. Corn was fed in both the spring and fall, although of course there was no shooting in the spring. As an example, Mr. Smith's notes show that 339 bushels of corn were fed in the spring of 1931.

A record of the kill of ducks was kept from 1925 until 1933 and is summarized by years in table 1.

TABLE 1.--ANNUAL KILL OF DUCKS AT FORK LAKE

Year	Number
1925	156
1926	199
1927	268
1928	738
1929	268
1930	287
1931	152
1932	613
1933	375
Total	3,056

Mr. Smith says that the average number of ducks visiting the lake was in the neighborhood of 25,000 each year. At one time in the spring of 1931 it was estimated that 20,000 ducks were on the pond and along the banks. Of these about 14,000 were mallards and 6,000 were pintails and a scattering of other kinds. In 1931 Mr. C. M. Powers and Mr. Dean Gorham, amateur ornithologists of Decatur, observed four European widgeons. Before that (1927) three male European widgeons spent three weeks on the pond. During most of the fall migration the mallard is the most numerous duck, although early in the season other ducks are common, such as blue-winged teal, green-winged teal, lesser scaup, ring-necked duck, widgeon and gadwall. Pintails are more common in the spring than in the fall. Black ducks increased each year from 1920 to 1931. Occasionally the lake has been visited by flocks of from 8 to 20 Canada geese. Buffleheads, shovellers and ruddies are rare. Since heavy feeding has been discontinued the number of ducks has declined sharply.

1938 FISH CENSUS

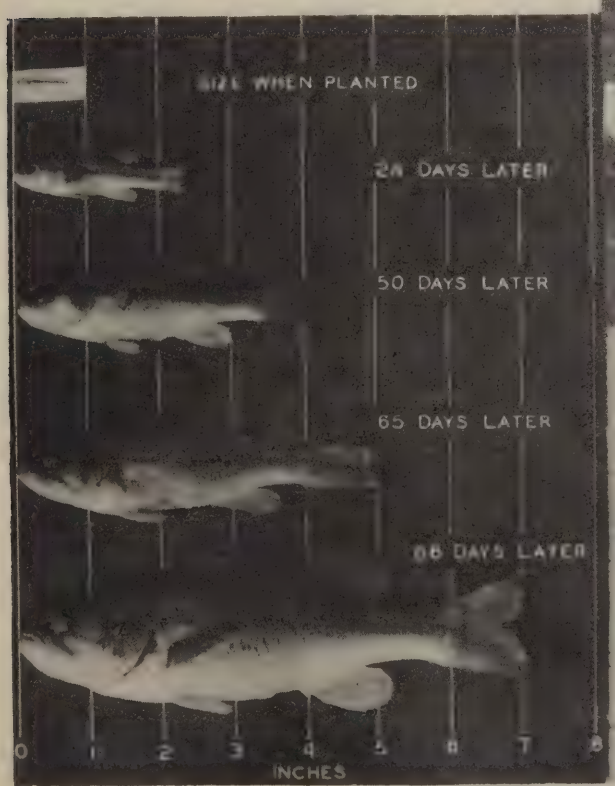
The fish of Fork Lake were killed by a single treatment with poison. The method developed by the Fisheries Institute of the Michigan Department of Conservation was

Above--Spring thaws bring mallards, black ducks, pintails, lesser scaups, ringnecked ducks, American widgeons, gadwalls, and other ducks to Fork Lake.

Right--Mallard drake coming in, photographed from blind.

Lower Right--Gathering poisoned fish along south shore of Fork Lake.

Below--Growth of largemouth bass fry after planting in Fork Lake on June 23, 1938.



used. Subsequent work has shown no evidence that any fish survived this treatment.

The poison was applied at 5:50 p.m., June 7, 1938. Within 15 minutes six fish were seen struggling at the surface of the water. As many more were seen within the next 10 minutes, in addition to several hundred inch-long buffalo fry that were dying. Within an hour redmouth buffalo and carp were gasping at the surface and the smaller kinds of fishes were dying rapidly. Before dark, three men had gathered up 748 black bullheads, 16 large buffalo and 3 carp.

When fish have been poisoned some of them float and can be picked up immediately, but a good share of them sink. In turbid water, or in deep water, dead fish cannot be gathered up until they bloat and rise to the surface. The surface of the lake was entirely cleared of fish each day for four days after the dose of poison. The numbers of each of the important species handled each day are shown in table 2. All of the fish handled after the first day had risen from the bottom of the lake.

TABLE 2.—NUMBERS OF FISHES RISING TO THE SURFACE EACH DAY AFTER POISONING

Kind	First Day	Second Day	Third Day	Fourth Day
Largemouth bass	.....	5	.....	.....
White crappie	29	72	6	6
Warmouth bass	1	29	.....	.....
Bluegill	9	106	.....	.....
Green sunfish	29	360	.....	.....
Orange-spotted sunfish	3	52	.....	.....
Channel cat	.....	4	.....	.....
Black bullhead	1996	1372	143	9
Redmouth buffalo	69	29	.....	.....
Carp	5	5	1	.....
Golden shiner	967	38	.....	.....
TOTAL	3108	2072	150	15

Twenty-two hours after the poison was applied collections were made with dip nets and minnow seines to find out whether other animal life had been affected. Samples were taken from the northwest shore of the pond (where the concentration of poison was highest) and from mud dipped from deep water. The numbers and kinds of living and dead invertebrates are given in table 3. The poison in the concentration used seems to be

TABLE 3.—KINDS AND NUMBERS OF AQUATIC INVERTEBRATES

Kind	Number Living	Number Dead
Crayfishes	7	....
Mayfly nymphs	6	....
Hydroporus	2	....
Palpomyia	7	....
Midge larvae	7	....
Pulmonate snails	8	7
Dragonfly nymphs	2	....
Oligochaetes	12	2
TOTAL	51	9

specific for fish. Most of the invertebrates were unaffected, and even gill-breathing vertebrates other than fish, such as frog tadpoles, survived.

The buffalo fry which died a few minutes after the pond was poisoned had almost disappeared by the next morning. They were eaten by the larger fishes, which were affected somewhat later. A large water snake (Natrix sipedon) was caught. Although unaffected by the poison, this snake was sluggish because it had swallowed about two pounds of fish. A pectoral spine of one of the bullheads had punctured its stomach and body wall, and yet it survived. A few small fish were eaten by birds, principally by the little green heron. No turtles were seen.

Dip nets were used from two boats to pick up fish. Other nets were used by men who walked along the shore or waded in the shallow water. The fish were sorted by species into tubs, buckets and baskets. Each kind was counted and then weighed in convenient lots on a Chatillon spring balance. This balance weighs to 60 pounds by 1-ounce intervals. It was suspended on a heavy tripod. The fish were weighed promptly after collection to avoid losses by drying. The standard length of almost every fish was taken on measuring boards to the nearest 0.1 inch. Lengths of all the numerous small black bullheads and golden shiners were not taken, but large representative samples were measured. The total numbers, total weights and average individual weights of the different kinds of fishes found in Fork Lake are shown in table 4. Length measurements of the more important species are grouped in ½-inch classes in table 5.

TABLE 4.—CENSUS OF ALL FISHES IN FORK LAKE, JUNE, 1938

Kind	Number	Weight, Pounds	Average Weight per Fish, Pounds	Per Cent of Total Weight
GAME FISH				
Largemouth bass	5	8.06	1.61	
TOTAL	5	8.06		1.1
OTHER "FINE" FISH				
White crappie	113	15.60	0.138	
Warmouth bass	30	1.47	0.049	
Bluegill	115	4.56	0.040	
Green sunfish	389	15.40	0.040	
Orange-spotted sunfish	55	1.31	0.024	
Sunfish hybrids	1	0.06	.....	
TOTAL	703	38.40		5.2
CATFISH				
Channel cat	4	4.56	1.140	
Black bullhead	3,520	301.90	0.086	
TOTAL	3,524	306.46		41.2
"ROUGH" FISH				
Redmouth buffalo	98	286.10	2.920	
Mongrel buffalo	1	6.06	.....	
Quillback	1	1.38	.....	
White-nosed sucker	1	0.75	.....	
Carp	11	58.90	5.350	
TOTAL	112	353.19		47.5
FORAGE FISH				
Golden shiner	1,005	37.90	0.038	
Common shiner	1	0.12	.....	
TOTAL	1,006	38.02		5.1

Total number of fish = 5,350
Total weight of fish = 744 lbs.

Number of fish per acre = 3,877
Weight of fish per acre = 539 lbs.

TABLE 5.—FREQUENCIES OF STANDARD LENGTHS OF THE MORE IMPORTANT FISHES.

Standard Length, Inches	White Crappie	Largemouth Bass	Carp	Redmouth Buffalo	Channel Cat
3	....	....	....	....	....
½	3	....	....	....	....
4	7	....	....	....	....
½	17	....	....	....	....
5	41	....	....	....	....
½	16	....	....	....	....
6	7	....	....	....	....
½	4	....	....	....	....
7	2	....	....	....	....
½	....	....	....	....	....
8	2	....	....	3	....
½	3	....	....	....	....
9	3	....	....	2	....
½	1	....	....	....	1
10	....	....	....	....	....
½	....	1	....	....	....
11	....	2	....	....	1
½	....	....	....	2	....
12	....	....	....	2	....
½	....	1	....	1	....
13	....	1	....	7	....
½	....	....	....	25	2
14	....	....	1	29	....
½	....	....	....	14	....
15	....	....	1	8	....
½	....	....	3	....	....
16	....	....	1	1	....
½	....	....	2	....	....
17	....	....	....	....	....
½	....	....	....	....	....
18	....	....	1	3	....
½	....	....	....	....	....
19	....	....	....	....	....
½	....	....	....	....	....
20	....	....	....	....	....
½	....	....	....	....	....
21	....	....	1	....	....
½	....	....	....	1	....
22	....	....	1	....	....
Number measured	106	5	11	98	4

Standard Length, Inches	Black Bullhead	Golden Shiner	Green Sunfish	Orange-Spotted Sunfish	Warmouth Bass	Bluegill
1	....	....	....	....	....	....
½	....	....	56	....	13	....
2	....	1	77	12	10	52
½	....	6	53	31	2	45
3	2	37	38	11	....	5
½	14	12	51	1	....	1
4	11	114	45	....	....	....
½	135	59	23	....	....	1
5	234	12	12	....	1	4
½	32	....	7	....	2	7
6	7	....	3	....	2	....
½	....	....	....	....	....	....
7	1	....	....	....	....	....
Number measured	436	241	365	55	30	115

Putrefaction was pronounced during the second and third days after poisoning, and it seems likely that there may have been weight shrinkage as great as 5 or 10 per cent due to bacterial action. No corrections have been attempted for such losses. Large representative samples were preserved for the Survey collections and for subsequent examination. Scales from several kinds were taken for age determination.

As many of the fry of the year as could be gathered up were preserved. These amounted to about one pound. All other fish were buried as fast as the observations on them were completed.

The four most abundant species (by weight) in Fork Lake were the black bullhead, redmouth buffalo, carp and golden shiner. Only 32 of the 3,520 black bullheads were large enough to be caught and dressed. Redmouth buffalo almost never take the hook. Carp bite more readily but few people are interested in fishing for them. The golden shiner is a large minnow but is not considered edible nor sought for by anglers. The numbers and weights of fish of legal size of those kinds which take the hook readily are given in table 6. These edible hook-and-line fish weighed 36.7 pounds, less than 5 per cent of the total weight of all fish.

TABLE 6.—HOOK-AND-LINE FISH OF EDIBLE SIZES

Legal Length, Inches	Kind	Number	Weight, Pounds
10	Largemouth bass	5	8.06
8	White crappie	16	6.28
6	Warmouth bass	5	1.25
5	Bluegill	12	2.63
5	Green sunfish	71	7.99
10*	Channel catfish	4	4.56
7*	Black bullhead	32	5.97
	TOTAL	145	36.74

* Arbitrary sizes chosen as the minimum for table use.

LIMNOLOGICAL OBSERVATIONS

At the time of the fish census the lake had a surface temperature between 80 and 90 degrees F. The water was thermally stratified and had a temperature approximately 70 degrees F. near the bottom. Later (August 10), during a period of very warm weather, temperatures and dissolved oxygen concentrations near the center of the lake were found as shown in table 7.

TABLE 7.—TEMPERATURES AND DISSOLVED OXYGEN CONCENTRATIONS, AUGUST 10, 1938

Depth, Feet	Temperature, Degrees F.	Dissolved Oxygen, Parts per Million
Surface	90.5	8.7
1	90.5	...
2	89.0	...
3	85.0	6.0
4	82.0	...
5	79.5	4.3
6	77.0	...
7	74.0	2.3

While the deeper samples showed depletion of oxygen, there was still sufficient for most of the kinds of fish found in Illinois lakes. Although the lake is protected

by trees on the east and south sides, it seems likely that north and northwest winds may occasionally cause complete circulation of the water.

At the time the lake was poisoned (June 7) objects were visible at depths of only 5 or 6 inches beneath the surface. About a week later the lake had cleared until objects could be seen at depths of about 3 feet. However, on August 10 the water was again turbid and gave a Secchi disc reading of 13 inches. This increase in turbidity was due, for the most part, to the activity of an enormous tadpole population, which survived the poisoning. During the two months following the poisoning these tadpoles had grown to unusually large sizes and roiled the lake by their repeated trips to the surface for air. Their numbers were in the thousands, perhaps even tens of thousands, and their total weight must have been several hundred pounds. By the end of September most of these tadpoles had metamorphosed into frogs and left the pond. Large numbers of young frogs were noticed below the spillway, hopping down the ravine toward Finley Creek and Lake Decatur. Tadpoles remaining in the pond were less active, and again the water became clear. Objects were visible in several feet of water early in November, 1938.

Although no chemical analyses of the water are available, it seems likely that droppings from the large numbers of ducks visiting the lake have materially increased the fertility of its water.

RESTOCKING WITH LARGEMOUTH BLACK BASS AND BLUEGILLS

Restocking of Fork Lake was begun as soon as the census was completed, four days after the poisoning. Between June 11 and 18, 270 adult bluegills between 5 and 7 inches long were brought from Homewood Fishing Club Lake at Decatur. Many of these bluegills were almost ready to spawn when they were planted. On June 22, 27 bluegill nests were counted along the north side of Fork Lake, 12 on the south side and 3 at the east end. A few newly-hatched fry were seen along the shore at this time. The bluegills continued to spawn throughout the summer. As a result, the 1938 broods of bluegills vary widely in size. On September 15 some were 3-3/4 inches long, while others were less than 3/4 inch.

On June 23, largemouth bass fry, estimated to be two or three weeks old, were seined from Homewood Lake and 1,440 of them were put into Fork Lake. They were counted, a dozen or two at a time, in a shallow white pan and examined to make sure no other kinds were present. These fry were of uniform size, averaging about 7/8 inch total length.

In Fork Lake they have grown at a rate which must be near the maximum for this latitude. Several times during the summer, samples of them were collected with a minnow seine and preserved. Their average lengths are shown in table 8. On August 25 one or two fish slightly over 6 inches in length were taken by Mr. Smith on a fly rod. The largest bass taken September 15 was 7.4 inches. On September 17, Mr. Smith took on a fly one that was 8.2 inches and another on September 24 a trifle over 9 inches.

TABLE 8.—GROWTH OF LARGEMOUTH BLACK BASS

Date	Number Measured	Average Standard Length	Average Total Length
June 23.	46	0.72	0.87
July 15.	11	2.07	2.53
August 10.	13	3.48	4.25
August 25.	46	3.76	4.62
Sept. 15	45	4.76	5.72
Oct. 4 and 21.	74*	5.29	6.45

* Taken on fly rod, measured and returned to water.

Throughout the summer and early autumn these bass were very fat and plump. On August 10, stomachs of three bass were examined. A 4-1/4 inch bass contained two crayfishes and several midge larvae; a 3-1/2 inch bass, a 1-inch bluegill and 20 or 30 midge larvae; and a 3-inch bass, two bluegills and several midge larvae. It seems likely that the larger bass were feeding on the smaller tadpoles before the latter metamorphosed. The bass taken on October 21 were noticeably slender and in poorer condition than were those taken earlier in the month.

RECOMMENDATIONS

Heavy hook-and-line fishing for both bass and bluegills should be carried on. No fish planting of any sort is recommended. Minnows or other fish should not be used for bait since they may escape and contaminate the pond. The water of Fork Lake is fertile, and no special feeding of the fish or fertilizing of the water seems necessary. In fact, there is danger that such practices may cause, during certain periods, serious oxygen deficiencies in the water.

The dam, the gullies leading into the lake and the shores should be planted to reduce erosion. This will help keep the lake clear, protect the dam and furnish a certain amount of food and cover for game. Plantings of submerged aquatic plants (Potamogeton) and of marginal plants (Sagittaria, etc.) will furnish food for waterfowl and support a variety of aquatic animal life useful as fish food.

Fish husbandry practices, which should be designed to fit the individual body of water, require an accumulation of pertinent information. A gage board should be set up and a record kept of fluctuations of the water level. Gage records should be kept in a bound book along with records of the fish removed, notes on fish predators, notes on waterfowl, occurrences of dead fish, etc. A written record of the catch of fish is particularly important since it is the only reliable measure of the success or failure of various management practices. The record book should be kept in a locked box (perhaps in the present duck blind) with keys carried by all persons permitted to use the lake. This box may also contain a spring scale and measuring board for recording the lengths and weights of the fish removed; a supply of scale envelopes to hold scales for age determination; a supply of labels, small cloth bags and a jar of formaldehyde (diluted with seven parts of water) to preserve stomachs for food analysis; and a Secchi disc for measuring the transparency of the water. A rough table near the duck blind would be a convenient place to clean fish and make these observations.

SUMMARY

1. There was good largemouth bass fishing for a few years after Fork Lake was built and stocked with fish.

2. Fishing became poorer year by year in spite of heavy stocking with bass and other kinds of hook-and-line fishes.

3. Accidental contamination with carp and buffalo, and by other kinds of fishes brought in as forage for bass, interfered with the growth and multiplication of the more desirable kinds.

4. Fork Lake was poisoned on June 7, 1938, and all of the fishes died within two hours. Some of the fish floated, but many sank. The latter bloated and rose to the surface during the next four days.

5. Frog tadpoles were unaffected by the poison, as well as insect larvae and most other aquatic invertebrates.

6. A complete fish census was made. A total of 5,350 fish weighed 744 pounds, the equivalent of 3,877 fish weighing 539 pounds per acre. About 5 per cent of the total, 36.7 pounds, were hook-and-line fish of edible sizes.

7. There were numerous indications of crowding and stunting among the catfishes and the various kinds of "fine" fishes.

8. In June, 1938, Fork Lake was restocked with 270 adult bluegills and 1,440 newly-hatched largemouth bass fry.

9. After the lake had been poisoned and restocked with bluegills and largemouth bass, its water became clear. These kinds do not roil the silt on the bottom as do carp, buffalo and bullheads.

10. Beginning a few days after restocking, the bluegills spawned throughout the summer and early autumn. Their fry were an important food for the rapidly-growing bass. A moderate number of the bluegill fry escaped being eaten and in October, 1938, the largest were 3 to 4 inches long.

11. Other important items in the diet of the bass were midge larvae, crayfishes and, probably, frog tadpoles.

12. In October, 1938, the bass averaged 6½ inches total length, with occasional individuals 8 or 9 inches long. They took the smaller artificial baits readily.

13. A map with soundings has been made of the lake. Some of the physical characteristics of its water were measured under summer conditions.

14. This pond has been visited by large numbers of ducks.

15. Suggestions for the improvement and management of Fork Lake during the next few years are outlined.

STATE OF ILLINOIS
Henry Horner, Governor
DEPARTMENT OF REGISTRATION AND EDUCATION
John J. Hallihan, Director

PROGRESS IN THE CONTROL OF ELM DISEASES IN NURSERIES

J. C. Carter

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PROGRESS IN THE CONTROL OF ELM DISEASES IN NURSERIES

J. C. Carter

An investigation of the effectiveness of fungicidal materials in controlling the elm diseases commonly known as "wilts"* has been underway since 1931. Reports of the results obtained have been made periodically, and this report brings up to date the information the investigation has yielded, particularly for experiments not completely reported on previously. A special point has been made, in two sets of experiments, of observing the effect of treatment on tree growth and on the sale value of the treated trees.

All of the tests have been conducted in commercial nurseries, in cooperation with the nurseries, and have been performed on trees receiving the cultivation usual in commercial production. The trees have been sprayed or dusted with fungicidal preparations containing either sulfur or copper. All of the dusts were sulfur dusts, and some of the sprays were sulfur sprays. All of the copper treatments were sprays.

The following specific materials were used: Koloform, Kolodust, dry wettable flotation sulfur, flotation sulfur dust, "Mike" sulfur, lime sulfur, a commercial Bordeaux, instant Bordeaux and Z-O. The characteristics of these materials are stated later.

Two of the experiments reported here have been in progress for several years and furnish data on the effectiveness of a commercial Bordeaux and two wettable sulfurs as summer sprays. Two other experiments, under way for four years, furnish data on the effectiveness of two copper sprays, instant Bordeaux and Z-O, used both as dormant and as summer sprays. The fifth experiment, also in progress for four years, furnishes data on the effectiveness of two wettable sulfurs as summer sprays with lime sulfur as a dormant spray. A sixth experiment only two years old gives preliminary indications of the value of "Mike" sulfur as a summer spray. The last experiment, under way for four years, gives data on the effectiveness of two summer sulfur dust treatments.

In these seven experiments over 6,500 trees have been used. The smallest number of trees used in any experiment was 400 and the largest number was 1,659.

MATERIALS

The sprays and dusts named above have the characteristics given below and each was used in the strength stated.

KOLOFORM is a wettable sulfur dust distributed by the Niagara Sprayer and Chemical Co., Inc. It contains not less than 54 per cent of sulfur, as the active ingredient, and not more than 46 per cent of inert ingredients. A portion of the sulfur is colloidal sulfur produced by the adsorption of molten sulfur by bentonite clay. It was used as a spray, at the rate of 15 pounds to 100 gallons of water.

KOLODUST is a sulfur dust also distributed by the Niagara Sprayer and Chemical Co., Inc. It is similar to Koloform but is adapted for direct use as a dust rather than as a spray ingredient. It contains not less than 87 per cent of sulfur, as its active ingredient, and not more than 13 per cent of inert ingredients.

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* The terms "wilt" and "elm wilt" have been in general use by nurserymen for years to designate any disease of elms that results in the wilting of any small or large part of a tree. It is used in this sense in this paper, rather than in the technically limited sense of the plant pathologist. The fungi most frequently associated with "wilting" of elms in the experimental plots belong to the fungus genera *Coniothyrium*, *Cytosporina*, *Phoma* and *Vermicularia* (see page 5).

This paper is a contribution from the Section of Applied Botany and Plant Pathology.

DRY WETTABLE FLOTATION SULFUR is an exceedingly fine, wettable sulfur dust formerly manufactured by the White Tar Company of New Jersey, Inc. It contains not less than 80 per cent of sulfur, the active ingredient, and not more than 20 per cent of inert ingredients. It was used as a spray, at the rate of 8 pounds to 100 gallons of water.

Dry wettable flotation sulfur has not been obtainable since 1936; and in the experiment in which it was in use (plot XII) "Mike" sulfur was used in 1937 and 1938.

FLOTATION SULFUR DUST is a sulfur dust formerly manufactured by the White Tar Company of New Jersey, Inc., for use as a dust rather than as a spray ingredient. It is otherwise similar to dry wettable flotation sulfur.

"MIKE" sulfur is a wettable sulfur dust manufactured by the Dow Chemical Company. It contains more than 95 per cent of sulfur as an active ingredient and less than 5 per cent of inert ingredients. It is composed of very minute particles, mixes readily with water for use as a spray ingredient and can be used also as a dust. As a spray, it was used at the rate of 8 pounds to 100 gallons of water.

LIME SULFUR, a standard fruit-tree fungicide, was used at a strength of 1 in 10. A liquid lime sulfur manufactured by the Grasselli Chemicals Department, E. I. duPont de Nemours and Co., Inc., was used as basic material.

COMMERCIAL BORDEAUX is a premixed preparation of lime and copper sulfate, which forms a Bordeaux spray mixture when added to water. The preparation used in our experiment was the Corona Bordeaux manufactured by the Corona Chemical Division of the Pittsburgh Plate Glass Company; this preparation contains not less than 13 per cent of copper as an active ingredient; and throughout the tests the spray used has been equivalent to 4-4-50 Bordeaux mixture.

INSTANT BORDEAUX is a homemade spray made with blue vitriol (copper sulfate) powder and dehydrated lime. It is prepared in the sprayer tank as it is needed and has the two practical advantages of being more quickly and easily prepared than regular Bordeaux mixture and of giving a more uniform and stable suspension of materials. In our experiment, instant Bordeaux was used at a strength equivalent to 4-4-50 Bordeaux mixture.

Z-O is a proprietary material sold in powdered form by the Niagara Sprayer and Chemical Co., Inc. It contains copper as an active ingredient in an amount equivalent, as metallic copper, to 25 per cent. It was developed as a material more convenient to use than Bordeaux mixture. Because of the gradual release of copper and the absence of lime, it is claimed that Z-O is less harmful to plants than any other copper-containing spray. It has proved effective for general spraying of ornamentals and for dusting truck crops. For both summer and dormant sprays, we used Z-O at the rate of 3 pounds to 100 gallons of water.

METHODS

From 1931 until the fall of 1935, liquid fungicides were applied in one plot with a 50-gallon, hand-operated spray outfit and in another plot with a 50-gallon power outfit. But since early in the spring of 1936 all spraying has been done with a 100-gallon Bean Little Giant Duplex outfit, operated at a pressure of approximately 275 pounds, thus eliminating lack of uniformity in spray applications. Dusting has been done with a Niagara blower dust gun that sends a good cloud of dust to a height of 8 to 10 feet, and dust applications have been made mostly in early morning when dew was on the foliage and before the wind became so strong as to prevent uniform dusting.

Summer applications of fungicides have been started in late April, May or early June, according to the season, and have been terminated in the latter part of August each year. In general, applications have been made at two-week intervals until the beginning of the dry weather period, usually about the middle of July, and then at three-week intervals during the remainder of the season.

SOME DISEASES OF NURSERY ELMS

A. *Cytosporina* infection in an advanced cankerous stage.

B. *Phoma* infection with the fungus sporulating through the bark.

C. *Vermicularia* discoloration in the wood.

D. Young *Coniothyrium* infection, typical of the first appearance of most wilts.

E and F. Advanced stages of *Coniothyrium* infection ready to produce spores.

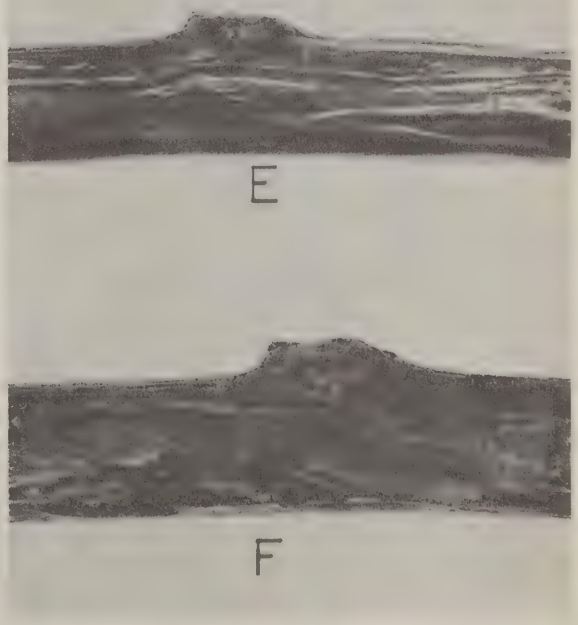

TABLE 1.--Disease control obtained from seven years of summer spraying and pruning.

Plot Number and Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease								Difference in Favor of (+) or Against (-) Treatment*	Percentage of Control (+) or Lack of Control (-)**
		1932	1933	1934	1935	1936	1937	1938	Total		
Plot VII											
Check	711	15	62	23	16	39	31	12	198		
Dry wettable flotation sulfur	474	16	23	26	16	37	....	....	118	- 22 trees	-14.2
Commercial Bordeaux . . .	474	18	21	29	20	28	17	11	144	- 18 trees	- 9.1
Plot IXS											
Check	254	5	14	50	51	23	20	6	169		
Pruning	282	....	....	....	31	31	20	13	95	+ 16 trees	+14.4
Koloform.	236	3	16	51	33	14	20	7	144	+ 16 trees	+ 8.5
Koloform and pruning*** .	230	2	13	49	31	13	20	10	138	+ 19 trees	+10.1

* Calculated on bases of 711 trees in plot VII and 282 trees in plot IXS.

** Percentage of control obtained as follows: $\frac{\text{Treatment difference}}{\text{Cases of disease in check}} \times 100$.

*** Sprayed seven seasons; pruned only the last four seasons.

Dormant sprays have been applied in March or early April, before the buds opened, and in October or November.

At regular intervals observations have been made and data recorded relative to the effectiveness of each of the fungicides used and to the prevalence of disease.

SEVEN-YEAR RESULTS FROM SUMMER SPRAYING

In two experiments dealing with over 2,600 trees, the relative effectiveness of summer spraying with commercial Bordeaux, Koloform and dry wettable flotation sulfur has been tested through periods of seven years for the first two sprays, and five years for the last named spray. In one experiment commercial Bordeaux and dry wettable flotation sulfur have been compared directly with each other, each on 474 trees, and with an untreated check group of 711 trees. In the other experiment Koloform alone and in combination with pruning (236 and 230 trees, respectively) has been compared with pruning (282 trees) and with an untreated check group (254 trees).

In these groups the majority of the trees that became diseased had been attacked by one of the *Phoma* wilts, but occasional trees were infected with *Cytosporina* and *Verticillium.*

The results obtained year by year and for the entire period of experimentation are shown in table 1. Five years of summer spraying with dry wettable flotation sulfur permitted the development of a greater number of infections than occurred, proportionally, among the check trees in the same period. Seven years of summer spraying with commercial Bordeaux also permitted a greater proportional development of disease than occurred among the check trees. Spraying with these two materials appears, in other words, to have favored development of disease to the extent of 14.2 per cent and 9.1 per cent, respectively, as indicated in the last column of the table.

Seven years of summer spraying with Koloform resulted in the occurrence of fewer cases of disease than among the untreated check trees. Similar spraying with the same material through seven years, with pruning added in each of the last four years, permitted development of fewer cases of disease, proportionally, than occurred among either the check trees or those only sprayed. The degree of control for spraying alone is indicated as 8.5 per cent and for the combination of spraying and pruning as 10.1 per cent. It is significant that a group of trees in the same block, given no treatment other than pruning and that for only the last four of the seven years, developed fewer new cases of disease during those four years than occurred in the check.

FOUR-YEAR RESULTS FROM SUMMER DUSTING

In an experiment involving nearly 1,400 trees the relative effectiveness of the sulfur dusts as summer applications, alone and in combination with pruning, has been under test for four years. Six applications of the dusts have been made each summer except 1937, when seven applications were made. Kolodust has been applied to the same groups of trees throughout the period. Flotation sulfur dust was applied to other groups of trees in 1935 and 1936; but, after this sulfur was not available, "Mike" sulfur was applied to these groups.

The prevalent infection in the plot was a species of *Phoma,* to which is attributable about 70 per cent of the total number of cases of disease. Most of the remainder of the infections were due to *Cytosporina.*

The results obtained year by year, and the degree of disease control for the entire period, are given in table 2. In the untreated, or check, group 171 trees, about 72 per cent, have become infected. But in the group in which pruning alone has been practiced, only 84 trees, about 39 per cent, have contracted disease. Summer dusting with Kolodust has permitted 149 trees, or about 64 per cent, to become infected; but the Kolodust treatment combined with pruning has permitted only 93 trees, about 47 per cent, to become infected. In the tree groups dusted first with flotation sulfur dust

TABLE 2.--Disease control obtained from four years of pruning, of summer dusting with sulfur and of summer dusting supplemented by pruning. (Plot XIV).

Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease					Difference in Favor of Treatment	Percentage of Control*
		1935	1936	1937	1938	Total		
Check	236	47	37	69	18	171		
Pruning	218	29	17	11	27	84	86 trees	47.0
Kolodust	235	40	41	40	28	149	23 trees	12.6
Kolodust and pruning	201	32	21	15	25	93	66 trees	35.5
Flotation sulfur dust and "Mike" sulfur**	253	36	50	22	19	127	56 trees	30.6
Flotation sulfur dust, "Mike" sulfur and pruning**	222	18	10	33	26	87	84 trees	45.9

* Calculated on the basis of 253 trees in each treatment.

** Flotation sulfur dust was applied in 1935 and 1936, "Mike" sulfur dust in 1937 and 1938.

and later with "Mike" sulfur, 127 trees, about 50 per cent, have become diseased; but in the group so dusted and also pruned only 87 trees, or 39 per cent, have become diseased.

Both dusting alone and dusting in combination with pruning appear in this experiment to have proved less effective than merely pruning out diseased material. This result is in accord with results reported previously for the early years of treatment in some of the first plots established. Although it may seem that the use of sulfur dusts is detrimental rather than useful, there are other considerations, such as the eventual disease control obtained over the growth-period of a block of trees and the extra growth resulting from the control of leaf spots and a great variety of minor pests.

FOUR-YEAR RESULTS FROM DORMANT AND SUMMER COPPER SPRAYS

The relative effectiveness of two copper sprays, applied as dormant and summer sprays alone and in combination with pruning, has been tested for four years in two experiments involving nearly 1,300 trees. In one of these experiments Z-O was applied alone to 143 trees and in combination with pruning to 133 trees, in comparison with 145 trees receiving pruning only and 136 untreated check trees. In the other experiment instant Bordeaux was applied to 178 trees and in combination with pruning to 186 trees, in comparison with 181 pruned trees and 186 check trees.

Most of the disease among these trees was the result of *Phoma* and *Coniothyrium* infections. A few cases were caused also by *Cytosporina* and by *Verticillium*.

The degree of disease control for the duration of these experiments and the results obtained each year are shown in table 3. In both sets of trees treated with Z-O, approximately 23 per cent of the trees became diseased during the four years, while about 35 per cent of the pruned group and 21 per cent of the check group became diseased. There were more cases of disease in the treated groups than in the untreated group of trees. In the pruned group 75 per cent more trees showed disease than in the untreated group, while the sprayed group and the sprayed and pruned group each had 13 per cent more trees that showed disease than had the untreated group.

In the experiment with instant Bordeaux, approximately 33 per cent of the trees sprayed with instant Bordeaux became diseased during the four years of the experiment, and about 14 per cent of the trees that were sprayed and pruned became diseased. In the check group about 26 per cent of the trees became diseased, and in the pruned group about 25 per cent became diseased.

These results indicate that the use of instant Bordeaux alone as both a dormant and summer spray tends to favor the development of disease, but that this treatment in combination with pruning gives a marked degree of control. The degree of control obtained with the combination of treatments, shown as 46.9 per cent in table 3, is actually 11 times greater than that given by pruning alone.

FOUR-YEAR RESULTS FROM DORMANT AND SUMMER SULFUR SPRAYS

A series of experiments to test the relative effectiveness of dormant and summer sulfur sprays has been in progress on approximately 850 trees for four years. Dormant applications of lime sulfur were made in the fall and in the spring on all sprayed trees and summer applications of two sets of sulfur sprays were made on definite groups of trees. The following sulfurs were used as sprays: Koloform, dry wettable flotation sulfur and "Mike" sulfur.

Koloform was applied alone to 136 trees and in combination with pruning to 141 trees. Dry wettable flotation sulfur was applied alone to 142 trees in 1935 and 1936 and was followed with "Mike" sulfur in 1937 and 1938. This same treatment in combination with pruning was given also to another group of 142 trees. For comparison a group of 145 trees were pruned and a group of 136 trees were left untreated, as checks.

Disease in these groups of trees was caused mainly by a *Phoma* and by a *Coniothyrium;* however, a few trees were infected with *Cytosporina* and a few with *Verticillium*.

TABLE 3.--Disease control obtained from four years of spraying with dormant and summer copper sprays.

Plot Number and Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease					Difference in Favor of (+) or Against (-) Treatment*	Percentage of Control (+) or Lack of Control (-)
		1935	1936	1937	1938	Total		
Plot XII								
Check.	136	12	9	3	3	27		
Pruning.	145	21	14	10	6	51	- 22 trees	- 75.9
Z-O.	143	18	12	2	1	33	- 4 trees	- 13.8
Z-O and pruning.	133	15	8	3	4	30	- 4 trees	- 13.8
Plot XIII								
Check.	186	26	11	9	3	49		
Pruning.	181	37	3	6	0	46	+ 2 trees	+ 4.1
Instant Bordeaux	178	40	14	2	0	56	- 10 trees	- 20.4
Instant Bordeaux and pruning	186	23	2	1	0	26	+ 23 trees	+ 46.9

* Calculated on the basis of 145 trees per block in plot XII and of 186 trees per block in plot XIII.

TABLE 4.--Disease control obtained from four years of treatment with lime sulfur as a dormant spray and with different sulfur summer sprays. (Plot XII).

Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease					Difference Against Treatment*	Percentage Showing Lack of Control
		1935	1936	1937	1938	Total		
Check.	136	12	9	3	3	27		
Pruning.	145	21	14	10	6	51	22 trees	75.9
Dormant and Koloform summer spray	136	13	14	10	1	38	12 trees	41.4
Dormant, Koloform and pruning. . .	141	21	5	8	2	36	8 trees	27.6
Dormant, dry wettable flotation sulfur and "Mike" sulfur summer spray**	142	13	15	8	1	37	9 trees	30.0
Dormant, dry wettable flotation sulfur, "Mike" sulfur and pruning**	142	36	8	5	0	49	21 trees	72.4

* Calculated on the basis of 145 trees in each treatment.

** Dry wettable flotation sulfur used in 1935 and 1936, "Mike" sulfur in 1937 and 1938.

The year by year results that have been obtained and the degree of disease control for the four-year period are given in table 4.

All of these treatments permitted the occurrence of a greater number of cases of disease than occurred proportionally in the check block, but the variations in cases of disease shown by the several treatments are not otherwise consistent. In the check group 20 per cent of the trees became diseased and in the pruned group 35 per cent became diseased. Of the trees given the Koloform summer spray 28 per cent contracted disease, and of those sprayed with Koloform and pruned 25 per cent contracted disease. Of those sprayed with dry wettable flotation sulfur and "Mike" sulfur 26 per cent became diseased, and of those so treated and also pruned 34 per cent became diseased. The group of trees that were pruned had 76 per cent more trees that showed disease than did the untreated group. In comparison with the per cent of disease in the untreated group of trees there was 41 per cent more disease in the group of trees that was treated with dormant and Koloform summer sprays. But there was only 27 per cent more disease in the group of trees that received this same spray treatment in combination with pruning.

In most of the treatments that were tested we have found that sprays in combination with pruning have given a greater degree of disease control than have applications of sprays alone. However, in this experiment the group of trees treated for two years with dormant and dry wettable flotation sulfur and then treated for two years with dormant and "Mike" sulfur had 42 per cent less disease than did the group of trees that received the same spray treatment but was tested in combination with pruning.

TWO-YEAR RESULTS FROM SPRAYING WITH "MIKE" SULFUR

In one experiment involving 400 trees the effectiveness of summer spraying with "Mike" sulfur has been tested for two years. "Mike" sulfur alone and in combination with pruning, each treatment on 100 trees, was compared with pruning (100 trees) and with an untreated check group (100 trees). Six applications of the spray were made each summer.

Most of the disease that has occurred in this plot has been caused by a *Phoma*, but a few *Coniothyrium* infections have also been found.

The results that were obtained each year and the degree of disease control for the two-year period of the experiment are given in table 5.

Two years of summer spraying with "Mike" sulfur resulted in 92 per cent less disease than was present in the untreated check group of trees. There was 46 per cent less disease in the group of trees that was sprayed with "Mike" sulfur in combination with pruning than in the untreated check group of trees. The group of trees that was pruned had 38 per cent more disease than did the untreated check group.

TABLE 5.--Disease control obtained from two years of spraying with "Mike" sulfur and from pruning. (Plot XV).

Treatment	Number of Trees Originally Present	Number of Trees Contracting Disease			Difference in Favor of (+) or Against (-) Treatment	Percentage of Control (+) or Lack of Control (-)
		1937	1938	Total		
Check	100	12	1	13		
Pruning	100	13	5	18	- 5 trees	- 38.5
"Mike" sulfur	100	1	0	1	+12 trees	+ 92.3
"Mike" sulfur and pruning.	100	6	1	7	+ 6 trees	+ 46.2

TABLE 6.--An estimate, on the basis of increase in trunk diameter, of the gain in sale value resulting from the spraying and pruning of trees for four years.

Plot Number and Treatment	Number of Trees Measured	Estimated Sale Value		Total Increase In Sale Value	Average Increase Per Tree in Sale Value	Calculated Gain in Sale Value per 1,000 Trees From Treatment
		Fall and Spring of 1934-35	Fall of 1938			
Plot VII (estimated in the fall of 1934)						
Check	258	$175.25	$590.45	$415.20	$ 1.61	
Dry wettable flotation sulfur spray	175	128.35	475.30	346.95	1.98	$370.00
Commercial Bordeaux spray	184	126.65	477.25	350.60	1.91	300.00
Plot XII (estimated in the spring of 1935)						
Check	101	63.70	203.45	139.75	1.39	
Pruning	120	80.15	252.85	172.70	1.44	50.00
Dormant, dry wettable flotation sulfur, "Mike" sulfur and pruning	101	67.35	243.80	176.45	1.75	360.00
Dormant, Koloform summer spray and pruning	99	58.70	222.25	163.55	1.65	260.00

In this experiment, "Mike" sulfur appears outstanding in its ability to control disease. However, the results of this experiment are parallel with the early results obtained in other previously reported experiments, in which combinations of pruning and spraying, as well as pruning alone, proved over a period of years to be the more effective treatments. Continuation of this experiment is necessary for a better evaluation of the effectiveness of this sulfur.

EFFECT OF TREATMENT ON TREE GROWTH

Two kinds of data have been kept which throw light on the effect of sprays on tree growth as a consideration separate from disease control. Measurements of tree diameters, made in connection with two of the spray experiments, give definite evidence that treated trees have grown better than untreated trees. Less definite, but perhaps equally indicative of the value of treatment, is the record of the number of trees selected and sold from one of the experimental plots.

DIAMETER MEASUREMENTS.--In the fall of 1934 diameter measurements were taken of the trees in the plot reported above as having received seven years of summer spraying with dry wettable flotation sulfur and commercial Bordeaux (see table 1, plot VII), and in the following spring similar measurements were made of trees in the plot reported as having received dormant and summer sulfur sprays for four years (see table 4). In the fall of 1938 diameter measurements were taken again of all of the trees then standing in these plots.

The individual trees measured in 1938 were selected from among those measured in 1934 and 1935, arranged in diameter classes differing by one-half inch, and valued according to wholesale prices of that date, to give their total sale value as of the winter of 1934-35. After measurement in 1938, they were again valued at wholesale prices, as of the winter of 1938-39, on the basis of one-half inch diameter classes. The increase in the sale value of check groups and of treated groups, after four years of growth, was determined by subtracting the 1934-35 valuation from the 1938-39 valuation. The results of this estimation are given in table 6.

For all treatments represented by an adequately indicative number of trees, there is definite indication that growth occurred more rapidly and that sale values increased more quickly in the treated than in the untreated trees. The increase in valuation averaged 30 cents per tree as a result of summer spraying with commercial Bordeaux and 37 cents per tree with dry wettable flotation sulfur. For pruning alone this increase amounted to 5 cents per tree, but with dormant and summer sprays combined with pruning this increase was respectively 26 cents and 36 cents per tree for the two types of summer sulfur sprays.

Although small per tree, these increases in value amount to considerable sums, as indicated in table 6, when considered as applicable to a thousand salable trees, and represent possible additional sale values of from $50 to $370 per thousand over trees receiving no treatment.

NUMBERS OF TREES SOLD.--During the winters of 1936-37 and 1937-38 the larger and better trees were selected by the nursery owner from one of the experimental plots, in order to fill purchase orders for trees of specified large diameters and high quality. The exact numbers of suitable trees found in the check group and in each of the treated groups are shown in table 7.

The advantage of treatment for disease control as a stimulant to more rapid growth is indicated by the fact that from 3 to 9 per cent more trees were selected from groups receiving some kind of treatment than from the untreated check group. These figures are the more significant, because the diameter specifications on which the selections were made were above the average run of the plot.

TABLE 7.--Number of trees sold from one experimental plot during the two winters, 1936-37 and 1937-38. (Plot IXS)

Treatment	Number of Trees Originally Present	Trees Sold		Total	Percentage of Trees Sold
		1936-37	1937-38		
Untreated	226	10	14	24	10.6
Pruning (four years). . . .	250	22	26	48	19.2
Koloform.	217	3	30	33	15.2
Koloform and pruning* . . .	200	3	24	27	13.5

* Sprayed for seven seasons; pruned only the last four seasons.

RESULTS

A recapitulation of the data presented in preceding pages is given in table 8, for direct comparison of the results obtained with the various treatments and combination of treatments.

These data indicate, as have the data in previous reports, that more than half of the different treatments tested have some value. The effective treatments, indicated by "+" signs in the table, range from 2 per cent to 92 per cent in their degree of effectiveness, and several--those effective to 30 per cent or more--are of practical value. As has been pointed out in previous reports, both ineffective and effective treatments for wilt control leaf diseases and stimulate tree growth.

The average percentages of control or lack of control shown in the last column of Table 8 are compared diagramatically in fig. 1. The bars reaching to the right of the vertical line represent effective treatments, those to the left represent ineffective treatments and the bar-lengths indicate degrees of effectiveness or ineffectiveness.

From fig. 1 and from table 8, it may be seen that the treatments that have been effective in the control of disease are (1) pruning, (2) instant Bordeaux in combination with pruning, (3) Koloform, (4) Koloform in combination with pruning, (5) "Mike" sulfur spray, (6) "Mike" sulfur spray in combination with pruning, (7) Kolodust, (8) Kolodust in combination with pruning, (9) flotation sulfur dust and "Mike" sulfur and (10) flotation sulfur dust and "Mike" sulfur in combination with pruning. The ineffective treatments are (1) commercial Bordeaux, (2) instant Bordeaux, (3) Z-0, (4) Z-0 in combination with pruning, (5) dry wettable flotation sulfur, (6) dormant and summer sulfur sprays and (7) dormant and summer sulfur sprays in combination with pruning.

It is shown in this report, as in previous reports, that most of the effective treatments involve either pruning or sulfur dusting. In addition, this report shows that two other treatments are effective, namely, spraying with Koloform and spraying with "Mike" sulfur.

Pruning, in most experiments, has shown a beneficial effect. But our experimental work has demonstrated that pruning does not always prevent the further development of disease. When, however, all diseased and discolored wood was removed, further progress of disease did not become evident for two or more years. In the trees in which disease recurred, it appeared that reinfection had taken place and that the disease was not a continuation of the original infection. In most of the pruned trees from which all of the discolored wood was not removed, disease continued to develop year after year. Pruning, when used in combination with instant Bordeaux, Koloform and the sulfur dusts, consistently increased the effectiveness of these treatments.

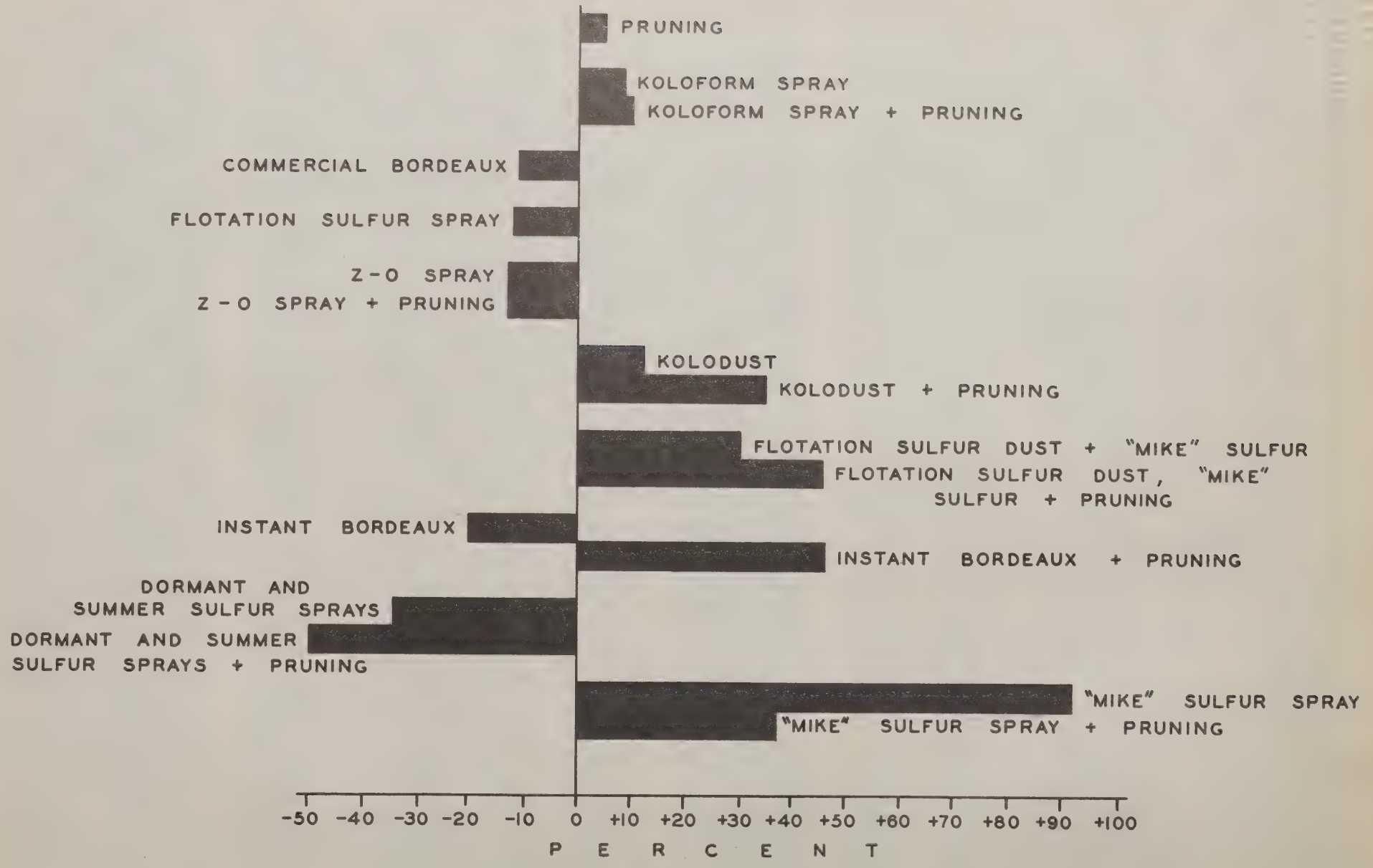
PRUNING
KOLOFORM SPRAY
KOLOFORM SPRAY + PRUNING
COMMERCIAL BORDEAUX
FLOTATION SULFUR SPRAY
Z-O SPRAY
Z-O SPRAY + PRUNING
KOLODUST
KOLODUST + PRUNING
FLOTATION SULFUR DUST + "MIKE" SULFUR
FLOTATION SULFUR DUST, "MIKE" SULFUR + PRUNING
INSTANT BORDEAUX
INSTANT BORDEAUX + PRUNING
DORMANT AND SUMMER SULFUR SPRAYS
DORMANT AND SUMMER SULFUR SPRAYS + PRUNING
"MIKE" SULFUR SPRAY
"MIKE" SULFUR SPRAY + PRUNING
-50 -40 -30 -20 -10 0 +10 +20 +30 +40 +50 +60 +70 +80 +90 +100
P E R C E N T

Fig.1.--Comparative degrees of disease control (+) and lack of control (-) obtained with various treatments of elms in nursery plots.

TABLE 8.--Recapitulation of the data to show the effectiveness of treatment on the occurrence of disease in nursery elms.

Treatment	Number of Groups of Test Trees Used	Total Number of Trees in Test Groups	Percentage of Control (+) or Lack of Control (-)		
			Least	Greatest	Average
Pruning	5	926	- 75.9	+ 47.0	+ 0.2*
Sulfur Dusts					
Kolodust	1	235	....	+ 12.6	+ 12.6
Kolodust and pruning	1	201	....	+ 35.5	+ 35.5
"Mike" sulfur (2 years), flotation sulfur (2 years).	1	253	....	+ 30.6	+ 30.6
"Mike" sulfur (2 years), flotation sulfur (2 years) and pruning	1	222	....	+ 45.9	+ 45.9
Sulfur Sprays					
Dry wettable flotation sulfur	1	474	- 14.2	....	- 14.2
Koloform	1	236	....	+ 8.5	+ 8.5
Koloform and pruning	1	230	....	+ 10.1	+ 10.1
"Mike" sulfur	1	100	....	+ 92.3	+ 92.3
"Mike" sulfur and pruning	1	100	....	+ 46.2	+ 46.2
Lime sulfur dormant and sulfur sprays	2	278	- 41.4	- 30.0	- 35.6*
Lime sulfur dormant, sulfur sprays (summer) and pruning	2	283	- 72.4	- 27.6	- 50.0*
Copper Sprays					
Commercial Bordeaux	1	474	- 9.1	....	- 9.1
Instant Bordeaux	1	178	- 20.4	....	- 20.4
Instant Bordeaux and pruning	1	186	....	+ 46.9	+ 46.9
Z-O	1	143	- 13.8	....	- 13.8
Z-O and pruning	1	133	- 13.8	....	- 13.8

* These averages were obtained by weighting data from individual groups in proportion to the number of trees in the groups.

Although the results given in this report have not been consistent in every respect with those given in previous reports, they agree in attributing to sulfur dusts the most uniform effectiveness in preventing new infections. The effectiveness of these dusts was greatly increased when they were applied in combination with pruning.

The use of copper and sulfur fungicides on nursery elms stimulates growth and especially the rate of diameter enlargement. These fungicides, when they are properly applied, also will control foliage diseases.

RECOMMENDATIONS

The growing of American elms involves two distinct problems in disease control. One is prevention of the leafspot and anthracnose diseases which recur annually and injure leaves and new growth more or less severely according to weather. The other is prevention and treatment of the group of destructive diseases known as wilts, which invade the interior of the tree and eventually result in the death of the tree.

CONTROL OF LEAF DISEASES.--Since elms are only retarded in growth by the attack of leaf diseases, control of those diseases has not generally been attempted. But the estimates given in this report, as well as those given in a previous one, indicate that considerable increases in growth and sale value can be obtained if spraying or dusting programs are followed which bring the leaf diseases under control.

For this purpose any of the sprays or dusts named herein are effective. Where this type of disease constitutes the chief problem, it is necessary to make only summer applications of fungicides. Dormant applications are likely to have little direct beneficial effect. It is important that spraying or dusting be done at relatively frequent intervals, so as to furnish protection continuously to the growing shoots and new leaves.

CONTROL OF WILT DISEASES.--Several of the treatments reported upon above have given control of wilt diseases to the extent of 30 per cent or more in comparison with lack of treatment in check groups of trees. These treatments, we believe, have practical value and may be used where the control of wilt diseases is the major problem. They are as follows:

1. Summer dusting with Kolodust, and pruning.

2. Summer dusting with sulfurs such as flotation sulfur dust and "Mike" sulfur, with or without pruning.

3. Dormant and summer spraying with instant Bordeaux, and pruning.

4. Summer spraying with "Mike" sulfur, and pruning.

In general, it appears advisable to rely on sulfur dusts, since they have given the most consistent results over a period of years of experimental tests.

The use of sprays for wilt should be avoided, generally, as for some reason most of them appear to favor development of greater numbers of wilt infections or, at best, give only a small degree of control. An exception is Bordeaux when combined with pruning, and a possible exception is "Mike" sulfur with or without pruning. Bordeaux combined with pruning is likely to be as effective as any of the sulfur dust treatments. Although "Mike" sulfur spray seems to have exceptional possibilities, the two years through which it has been tested are not sufficient to prove its full value.

Pruning, although not uniformly dependable as an individual means of disease control, is essential if best results are to be obtained from the use of most of the effective fungicides. Pruning in connection with disease control, it should be understood, is more than the usual shaping of the growth habit of the tree. Its purpose is to remove completely all infected material, even to the extent of the destruction of an entire tree when needful.

INSTRUCTIONS

In order to obtain satisfactory results with the treatments recommended above, it is necessary to follow a consistent schedule in the application of the fungicides, to use them in effective concentrations and, in pruning to carry out the operation faithfully.

SCHEDULES FOR TREATMENT.--Dormant sprays may be applied at the grower's convenience. It is desirable that two such sprays be used. The first application should be made shortly after the beginning of the dormant period and the second should be made near the close of the dormant period. Since these are in the nature of "clean-up" treatments, their effectiveness is probably increased by the higher fall and early spring temperatures.

During the summer, the sprays or dusts used should be applied at regular intervals. The first application should be made as soon as the first leaves are well grown. The time of this first application will of course vary from season to season. Applications should then be made at two-week intervals through June or, if the weather continues moist, until mid-July. During July and August the period between applications may ordinarily be lengthened to three weeks.

Pruning for disease control is best done just before each of the periodic applications of fungicides. If pruning is done immediately preceding each spraying, a regular schedule is maintained and trees are freed of infection before being treated. Naturally, better results follow.

SULFUR DUSTS.--Sulfur dusts are used in the form in which they are received. No diluting or mixing with other materials is required. Dusts can be applied with either hand- or power-driven dusters, depending on the size of the trees to be cared for. Hand-power dusters send a satisfactory dust cloud to a height of only about 10 feet beyond the duster nozzle. Trees over 15 feet tall should be dusted with a power duster.

Preferably, dusting should be done in early morning while there still is dew on the foliage and before the wind becomes strong, but it may also be done after a light rain, while the foliage is still damp.

SULFUR SPRAYS.--In the preparation of sulfur sprays fine wettable sulfur dusts are mixed directly with water in the spray tank. Directions as to the amount of dust needed for an effective spray usually are given on the manufacturer's package or label. Koloform, which is recommended above, should be mixed with water at the rate of 15 pounds per 100 gallons. "Mike" sulfur, also recommended, should be used at the rate of 8 pounds per 100 gallons. A good, even distribution of the dust in the water results from a few minutes' operation of the agitator in the spray tank before spraying is begun.

INSTANT BORDEAUX.--Instant Bordeaux equivalent to the usual 4-4-50 Bordeaux mixture is desirable. For this strength 8 pounds of powdered blue vitriol (copper sulfate) and 8 pounds of superfine hydrated lime are required for each 100 gallons of water. In the preparation of the mixture, about one-fourth the required amount of water is run into the spray tank and then the blue vitriol powder, and afterwards the lime, are washed through the intake strainer as the tank is filled. A minute's operation of the agitator in the spray tank before spraying is begun gives all the mixing that is necessary.

PRUNING.--The effectiveness of pruning, whether used alone or in conjunction with other treatments, is dependent on the thoroughness with which it is done. In pruning for disease control, it is absolutely necessary that all wood containing discolorations be removed, and it is best to continue cutting back until a foot or more of clean, healthy wood has been removed below the part which is diseased. Sterility of the pruning instruments is essential to prevent spread of disease during the operation. It is better to cut out too much than too little.

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